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Development of Motion-Picture Positive Film by Vanadous Ion

By A. A. RASCH and J. I. CRABTREE

The inorganic developer system of Roman, employing divalent vanadium ion as the active developing agent, has been further investigated. A solution prepared from vanadium pentoxide, sulfuric and hydrobromic acids, and reduced by electrolysis was found to double the speed of motion-picture positive emulsions with development times of the order of 20 sec at 60 F. Other sensitometric properties can be controlled to match those produced by conventional processing. A motion-picture film-processing machine employing the vanadium developer has been devised and tested and is described. Developer activity is maintained by continuous electrolytic regeneration of the solution, with replenishment made only to balance carry-over losses.

Early Work

Photographic developers which employ a metal ion as the active developing agent have been known for a long time. Perhaps the most well-known system is that using ferrous iron.[1] Others, using chromium,[2,3] tungsten[3] and molybdenum,[3] have been investigated to a lesser extent over the past sixty years. Some work has also been carried out with metal-ion systems in which the metal ion is tied up with a chelating agent, and a recent paper describes the use of trivalent titanium in such a system.[4] From a practical standpoint, none of the developers investigated were found to be of much interest because of their low activity, very short exhaustion life, and poor stability.

Divalent vanadium has also been known to have photographic activity as early as 1894, when A. and L. Lumière[5] described the preparation of a vanadium developer solution. However, the Lumières were more interested in the use of vanadium salts as the light-sensitive material in printing out emulsions and did not fully investigate the use of vanadium in developers. Subsequent reference to vanadium as a developing agent[6] gives very little experimental data.

Recently a French photographic chemist, Pierre Roman, initiated a new series of investigations of the metal-ion developer system.[7] He calculated that any metal-ion system having a standard reduction potential more negative than

Communication No. 1616 from the Kodak Research Laboratories, by A. A. Rasch and J. I. Crabtree, Research Laboratories, Eastman Kodak Co., Rochester 4, N.Y. The paper was presented on October 6, 1953, at the Society's Convention at New York.
(This paper was received October 2, 1953.)

Table I. Metal-Ion Systems Which Will Reduce Silver Bromide in a Silver Bromide–Bromide-Ion System.

$Ti^{4+} + e = Ti^{3+}$	$E =$ 0.03 to 0.06 v	pH = $\bar{1}$ to 3
$W^{6+} + 3e = W^{3+}$	$E =$ 0.0	pH = 0
$V^{3+} + e = V^{2+}$	$E =$ −0.2	pH = 0
$Ti^{3+} + e = Ti^{2+}$	$E =$ −0.4	pH = 1
$Cr^{3+} + e = Cr^{2+}$	$E =$ −0.4	pH = 0
$Sn^{4+} + 2e = Sn^{2+}$	$E =$ −0.7	pH = 11

+0.120 v would be capable of reducing silver bromide in a silver bromide–bromide-ion system. More accurately, he calculated that the metal-ion system would have to satisfy the equation:

$$-0.058 \log (Br^-) - E - \frac{0.058}{n} \log \frac{(ox)}{(red)} > -0.006,$$

where

(Br^-) = bromide-ion concentration,
E = standard reduction potential,
n = electron change in the reaction,
(ox) = concentration of oxidized state of metal ion, and
(red) = concentration of reduced state of metal ion.

Roman also decided to limit his investigation to systems which are not greatly affected in activity by reasonable changes in the concentration of the oxidized form of the active compound. The system should also meet the final requirement that both oxidized and reduced forms of the active agent be soluble and dissociated.

With these requirements in mind, Roman found that the systems listed in Table I were of possible interest. Tin was eliminated because of its nonselective development characteristics, and chromium for the same reason. The divalent–trivalent titanium system was too unstable for practical use, while the other titanium system was too inactive. Solubilizing the tungsten required the use of hydrofluoric acid which, for obvious reasons, was unsuitable.

The vanadium solution, however, could be readily prepared and was found to be an active developer. Vanadium pentoxide was found to be commercially available and a suitable starting material for the preparation of the developer.

By using one of several possible methods described below, the vanadium pentoxide can be dissolved in a strongly acid solution. This solution is then electrolyzed to reduce the vanadium to the divalent state. Roman found that this solution was a very active developer, giving especially good results with motion-picture positive-type emulsions. When such a solution is used for development, the divalent vanadium is oxidized to the trivalent state, and, since the reaction is reversible, the divalent vanadium can be re-formed by further electrolysis which, as will be seen, is a feature of this metal-ion system.

Subsequent to this original work by Roman, an extensive investigation of the vanadium developer system has been made in the Kodak Research Laboratories to determine the solution composition for producing optimum results on motion-picture positive-type emulsions. An experimental machine has been designed for processing with the vanadium developer which includes a means of maintaining developer activity by electrolytic regeneration.

Preparation of Vanadium Developer

Although a number of vanadium compounds are available commercially, vanadium pentoxide is by far the cheapest but it is somewhat difficult to compound in a developer, being only slightly soluble in dilute sulfuric acid but more readily soluble in hydrobromic acid.

Roman has described a method of solution in which sulfur dioxide is bubbled through a mixture of vanadium pentoxide and hydrobromic acid. The sulfur dioxide reduces the vanadium from the pentavalent to the readily soluble tetravalent state, as illustrated by the following equation:

$$V_2O_5 + 2HBr + SO_2 = VOSO_4 + VOBr_2 + H_2O. \quad (1)$$

The resulting solution can then be electrolyzed to form the divalent vanadium.

This method was at first used for the preparation of the various solutions used in the current experiments. However, traces of sulfur dioxide left in solution eventually formed compounds which greatly increased the fogging propensity of the developer and, since removal of the last traces of sulfur dioxide proved to be quite difficult, alternative methods of dissolving the vanadium pentoxide were sought.

One method consisted in heating the pentoxide with a warm mixture of hydrobromic and sulfuric acids, so that the bromide ion reduces the vanadium to the tetravalent state, and bromine gas is liberated, as in the equation:

$$V_2O_5 + 6HBr = 2VOBr_2 + 3H_2O + Br_2. \quad (2)$$

This method was used for some time but was always considered objectionable because it was necessary to dispose of a considerable quantity of the highly corrosive and noxious bromine gas byproduct.

More recently, it was found that the vanadium pentoxide dissolves quickly in a solution of oxalic acid in concentrated sulfuric acid. The vanadium is reduced to the tetravalent state while carbon dioxide is formed as a byproduct.

$$V_2O_5 + H_2C_2O_4 + 2H_2SO_4 = 2VOSO_4 + 2CO_2 + 3H_2O. \quad (3)$$

This method is much more desirable, especially when preparing large batches of the developer.

Once the solution containing the tetravalent vanadium ion has been formed, the extra acid as required by the developer formula is added and the solution is diluted to volume.

To prepare the photographically active divalent vanadium ion, the solution is placed in an electrolytic cell and electrolyzed. A cell essentially similar to that described by Roman has been used for all the preparations, consisting of a noncorroding cylindrical tank made from materials such as Plexiglas or Type 316 stainless steel. A sheet-lead liner insulated from the tank constitutes the cathode, and an unglazed porcelain cup centered in the tank contains a carbon rod, such as is used in chlorine cells, which serves as the anode.

The vanadium solution serves as the catholyte while the anolyte consists of a solution of sulfuric acid equal in total acidity to that of the vanadium solution.

Direct current is supplied to the cell from a selenium rectifier or a d-c generator. Suitable provision is made to stir the solution in the cathode compartment, and the whole unit is surrounded by a cold water cooling-jacket.

The laboratory cell described has a total cathode area of 0.12 sq m, upon which a current density of 250 amp/sq m is maintained, or a total of 30 amp, at a potential of 5 to 6 v across the cell.

The reduction process is accomplished at a current efficiency of 70%, with the result that this cell can prepare the usual developer solution at a rate of about 1 liter/hr.

The vanadium ion is reduced at the cathode in two steps:

$$VO^{+++} + 2H^{+} + e = V^{+++} + H_2O, \quad (4)$$

and

$$V^{+++} + e = V^{++}. \quad (5)$$

Reaction (4) will proceed to completion using only slightly more than the theoretical current consumption, the loss in current efficiency being due to the evolution of heat. However, reaction (5) never goes to completion and in reducing 85 to 90% of the trivalent vanadium to the divalent state, current efficiencies of 50% or less prevail. This severe drop in current efficiency is the result of competition between the following reaction and reaction (5) at the cathode,

$$2H^{+} + 2e = H_2. \qquad (6)$$

Normally, it would be expected that reaction (6) would be predominant, since the standard emf's of the two systems would indicate that hydrogen ion would more readily accept an electron than would trivalent vanadium ion. However, owing to the fact that the lead cathode has a very high overvoltage to the hydrogen-forming reaction, trivalent vanadium will be more readily reduced. When about 70% of the vanadium has been reduced to the divalent state, hydrogen gas begins to form at the cathode, and the rate of formation increases quite rapidly as electrolysis proceeds. It has been found impractical to carry the electrolysis beyond the point where 85% of the vanadium has been reduced, since current efficiency at this point is extremely low. From a photographic standpoint, further electrolysis would be unnecessary since the developing capacity of the solution at this point is ample.

During the early stages of the electrolysis, oxygen forms at the anode,

$$2H_2O = O_2 + 4H^{+} + 4e, \qquad (7)$$

but, as electrolysis proceeds, a certain amount of bromide ion diffuses through the porous cup from the cathode compartment and is immediately oxidized to bromine.

$$2Br^{-} = Br_2 + 2e. \qquad (8)$$

The amount of diffusion of bromide ion that occurs during the preparation

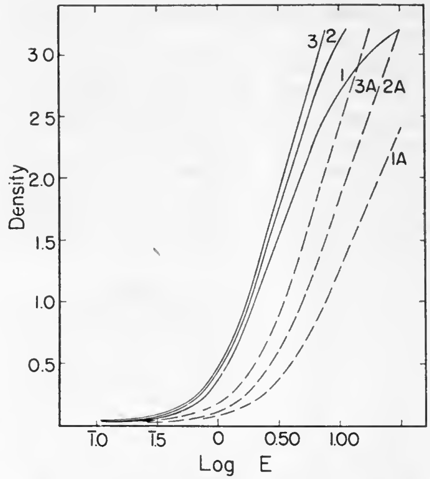

Fig. 1. Characteristic curves produced by vanadium development of Eastman Fine Grain Release Positive Film, Type 5302. Development times of 25, 30, and 35 seconds at 60 F are represented by Curves 1, 2, and 3. These are compared with development times of 3, 5, and 8 minutes at 68 F in Kodak D-16 Developer, producing Curves 1A, 2A, and 3A.

of small batches of solution does not significantly change the composition of the developer. In the case of a long-term electrolysis, proper balancing of the concentrations of the starting components can be made to balance the effect of the electrolysis.

Properties of Vanadium Developer

The solution thus prepared is an extremely active developer for emulsions such as Eastman Fine Grain Release Positive, Type 5302. As shown in Fig. 1, developing for times ranging from 25 to 35 sec will produce sensitometric curves very similar to those produced in 3 to 8 min in a conventional Metol-hydroquinone developer, such as Kodak D-16. The vanadium development gives substantial increases in speed, amounting to more than twice that

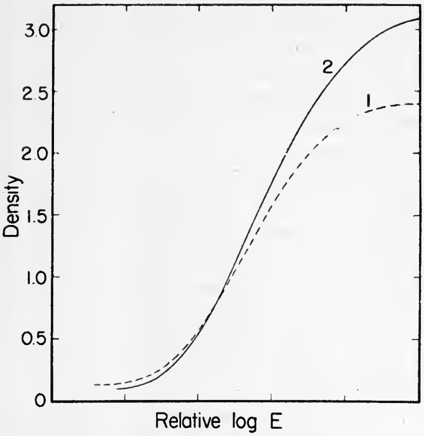

Fig. 2. Effect of degree of agitation on vanadium development. Curve 1 was produced by still development, and Curve 2 using high agitation for the same time of development.

produced by the conventional developer. There is some tendency, however, for shoulder densities to be a little low and, unless proper precautions are taken, fog values will be high.

The kinetics of vanadium development were investigated extensively by L. J. Fortmiller and T. H. James, of these Laboratories, and the complete description of this work appears in a forthcoming separate article.[8] The development reaction can be most simply stated as follows:

$$V^{++} + Ag^{+} = Ag + V^{+++}. \quad (9)$$

James and Fortmiller found that the rate of development is proportional to the concentration of vanadous ion up to a concentration of 0.1 *M*, but drops somewhat below direct proportionality at higher concentrations, and the rate is essentially independent of vanadic-ion concentration. There is no significant induction period and development starts immediately. The rate of development under most practical conditions appears to be largely controlled by the rate of diffusion of developer through the gelatin layer, and therefore is markedly influenced by agitation.

The differences in sensitometric properties that can be produced by varied agitation are demonstrated by the curves in Fig. 2. When comparing high agitation with still development, it is seen that for the same time of development much higher shoulder densities and higher gamma are produced when high agitation is used.

Roman obtained best results with vanadous bromide dissolved in hydrobromic acid of about 2.35 *M* concentration. The optimum concentration of vanadous bromide was about 0.4 *M*. He also tried sulfuric and hydrochloric acid solutions of vanadium but obtained lower image densities and higher fog values.

Roman's optimum formula did not give best results with Eastman Fine Grain Release Positive Film, Type 5302, available in this country. The formula used to produce the results shown in Fig. 1 was the result of experiments in which a systematic variation of the various developer components was made.

The optimum vanadium-ion concentration was found to be 0.35 – 0.45 *M*, which is in agreement with Roman's work. However, better results could be obtained with a mixture of hydrobromic and sulfuric acids rather than by using either one alone.

Fog development varied quite widely with the sulfuric and hydrobromic acid concentrations, minimum fog values being obtained when the ratio of the equivalent sulfuric acid to hydrobromic acid concentrations was 4:1. Fog and speed values varied with the total acidity of the developer, a total acidity of 3 normal being optimum.

Combining these values, a formula containing 0.44 mole of vanadium, 80 to 85% of which is in the divalent state, 2.4 equivalents of sulfuric acid, and 0.6 equivalent of hydrobromic acid gave best results. Development of motion-picture positive-type film to normal gamma required 15 to 25 sec. In terms of weights and volumes of starting materials, the optimum experimental formula was as follows:

Vanadium pentoxide	40 g
Hydrobromic acid (48%) . .	68 ml
Sulfuric acid (95%)	68 ml
Water to make	1 l

(28 g of oxalic acid used to dissolve the vanadium pentoxide)

Since this formula gave fog values somewhat higher than desired, the addition of antifoggants was investigated. Conventional organic antifoggants, such as benzotriazole and 6-nitrobenzimidazole, were ineffective but low concentrations of potassium iodide in the order of 0.05 g/l maintained fog at acceptable levels.

The temperature of development, while controlling development rate, has an appreciable effect on fog formation. Best results are obtained at a temperature of 60 F, below which there appears to be no reduction in fogging propensity.

The temperature coefficient of development is low, being about 1.5 for a 18 F (10 C) change of temperature. However, the temperature coefficient of fog development is higher than that of image development and therefore the developer has less selectivity at higher temperatures.

The characteristics of images produced by vanadium development show some marked differences from those produced by conventional developers. Photomicrographs of cross sections of a vanadium-developed image show that image silver tends to be concentrated more toward the surface of the emulsion than is the case with conventionally developed images. Where there is high fog, silver is deposited predominantly near the base, and the extent of this fog silver varies inversely with the amount of image silver produced.

The image tone produced by vanadium development is somewhat colder than that produced by conventional development but the graininess of the two images remains essentially equal. In terms of speed-graininess ratio, vanadium development appears to give a considerable improvement over conventional processing.

The relatively high acid concentration of the vanadium developer is necessary to prevent hydrolysis of the vanadous ion and subsequent precipitation. The high acidity will cause serious swelling or solution of the gelatin unless the photographic emulsion used is prepared with hardened gelatin, or is hardened before development.

The physical stability of fine-grain positive emulsions when processed in vanadium solutions is excellent, despite the extreme acidity of the solution. This is due, in part, to the short development time, the low temperature of processing, and the hardening action of the vanadium ion. If the temperature of processing is raised to 75 F, softening and reticulation of the emulsion may occur even during the short developing times.

A Vanadium Processing Machine

The various experiments leading to the results already described were made using hand-processing techniques. As a step toward reducing the vanadium development system to practice, a small continuous processing machine was built for processing projection lengths of motion-picture prints. Because of the highly corrosive nature of the vanadium developer solution, the developing section must be made from noncorroding materials, such as Plexiglas and Type 316 stainless steel. Figure 3 is a schematic representation of the vanadium processor.

Immersed-jet agitation is used in the developing tank and the developer from the tank flows through an electrolytic cell similar to that already described. The developer is pumped from the cell through a thermostatically controlled

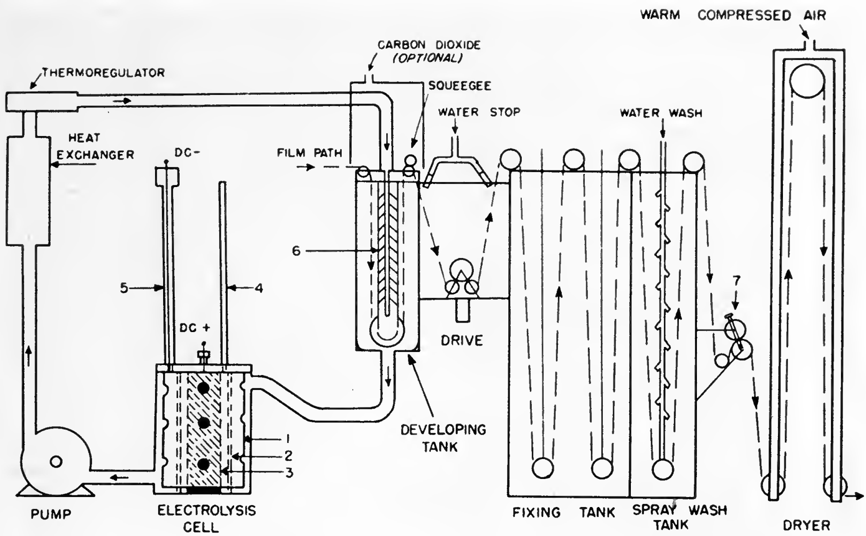

Fig. 3. Schematic representation of vanadium processing machine: 1, lead cathode; 2, porous cup; 3, carbon anode; 4, vent:anode compartment; 5, vent:cathode compartment; 6, column of orifices through which developer is forced to give immersed-jet agitation; 7, drive and squeegee. Arrows in developer recirculation system show the direction of solution flow. The electrolysis cell, the developing tank, and the drying cabinet are of Plexiglas, while all other parts that come in contact with solutions are of Type 316 stainless steel.

heat-exchange system back to the immersed jets of the developing tank.

The electrolytic cell in the system serves as a novel method of maintaining developer activity. Oxidized vanadium formed by the development process and aeration is electrolytically reduced in the cell and the composition of the developer remains essentially constant. The only loss is represented by the amount of solution carried out on the film, and with proper squeegeeing, this may be kept at a low level. Runs have been made where carry-out rates of approximately 0.3 ml/ft of 35mm film have prevailed.

After development, the film immediately passes through a spray water rinse which acts as a stop bath. From this point, the film is conventionally fixed, washed and dried, except that an ammonium hypo fixer, spray wash and warm, forced-air current are employed, so that the rate of these processing steps will be consistent with the developing rate. Figures 4 and 5 show the experimental machine with which the vanadium development tests were made.

Processing Procedure

Using the optimum vanadium developer formula, Eastman Fine Grain Release Positive Film, Type 5302, is developed in 15 to 20 sec at 60 F on the experimental machine with a film speed of about 6 ft/min. The developing section is charged with a solution prepared in an external electrolytic cell, the electrolysis being performed external to the machine primarily to save time. Continuous electrolytic regeneration of the vanadium developer during a processing run requires relatively little current and consequently the electrolytic

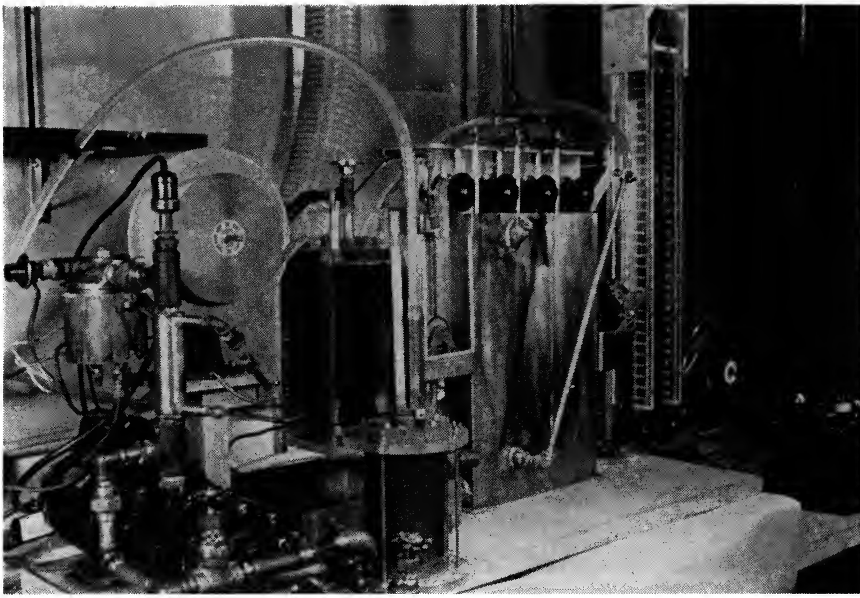

Fig. 4. General view of vanadium processing machine.

cell in the machine need not have a very high capacity. However, if the machine were filled with unelectrolyzed developer at the start, it would require an unreasonable amount of time to bring the solution up to proper activity with the low-capacity machine cell.

Replenishment to maintain volume of solution in the system can be made with either the electrolyzed or non-electrolyzed solution. The replenisher solution has essentially the same composition as the starting solution, with the possible exception of a slightly lower bromide concentration. At the carry-out rates found on the machine, as much as 3300 ft of 35mm film can be processed in 1 liter of vanadium developer solution. The bromide build-up in the developer caused by this high processing capacity will be at least partially compensated for by the electrolysis. Bromide ion diffusing into the anode compartment of the machine cell is oxidized to bromine gas and thus removed from the system. If this is not enough, the composition of the replenisher solution is adjusted accordingly.

Runs of up to 8000 ft have been made on the processing machine using Eastman Fine Grain Release Positive Film, Type 5302. Electrolytic regeneration of the developer was used, as already described, to maintain developer activity, and throughout the run it was possible to produce reasonably constant photographic results.

To keep a check on the developer composition during processing, an analysis procedure has been devised that requires no more equipment, time and skill than the procedure used in control analysis currently practiced by motion-picture processing laboratories.

There appears to be no necessity for special techniques in processing other than to observe the following precaution. Since the vanadium solution is very sensitive to aerial oxidation, care must be taken to prevent undue exposure to air, otherwise very rapid oxidation of the developer will occur and there will be a tendency for aerial fogging reactions.

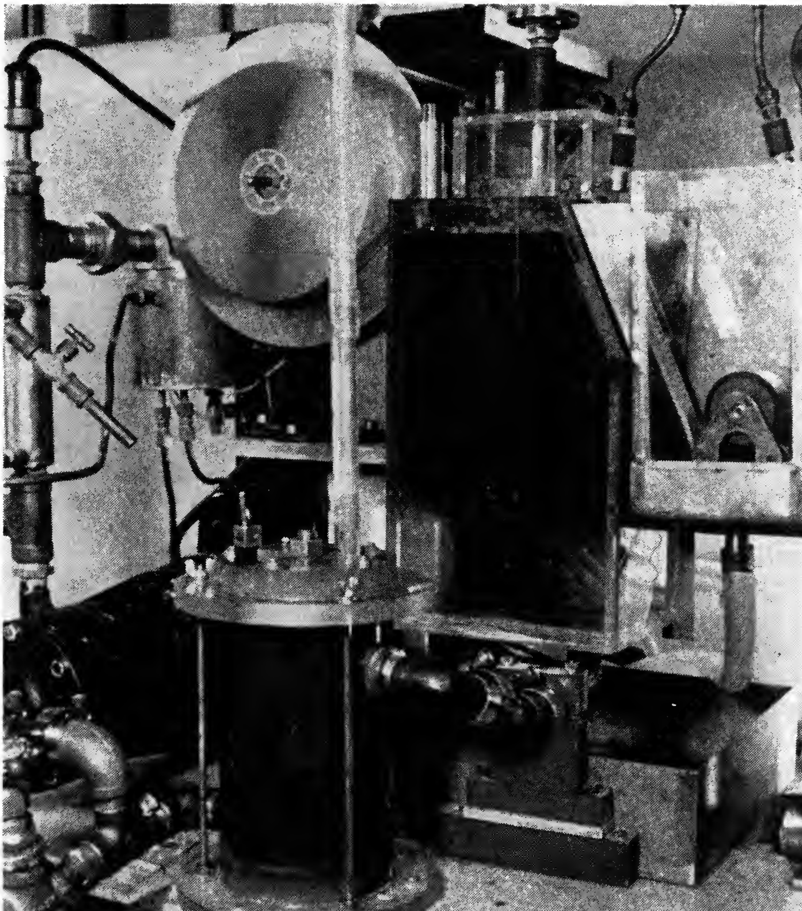

Fig. 5. Developing and regeneration sections of vanadium processing machine.

A carbon dioxide gas blanket was maintained over the developing-tank head on the experimental machine since there was a tendency for air to be sucked into the system. It is believed, however, that an improvement in design will eliminate this necessity and the slight oxidation that would occur could be balanced by electrolytic regeneration.

Potential Applications

At present, the only potential users of the vanadium system for processing motion-picture positive film are the large-scale laboratories that already have the facilities and skilled personnel necessary. The advantages of rapid development rate, effective speed increase, improved image tone, and high capacity of the vanadium development system are offset by the necessity of handling a corrosive solution, a noxious gas, and using special equipment. Further study and development will be necessary to determine the ultimate practicability of the vanadium system but it represents a pioneering effort in the use of inorganic salts for developing photographic emulsions.

Although this paper has dealt mainly with the processing of positive emulsions, some results have been obtained in other applications. In general, results with high-speed negative emulsions have been much poorer, at least when using the optimum vanadium formula mentioned. The large speed increases associated with processing positive films have not been obtained in these cases. Better results have been obtained when processing fine-grain recording materials, such as Kodak Recordak and Microfile films, but more complete tests with a wide variety of emulsions are in progress.

Acknowledgment

The authors are indebted to C. J. Kunz for assistance in the design of the processor.

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Discussion

John A. Maurer (J. A. Maurer, Inc.):It was mentioned that no sound track was made on this film. It was also mentioned during the paper that the vanadium has a hardening effect on the portion of the film where the image is developed. Of course, we're all familiar with the fact that in ordinary development an image in relief is generally produced. This relief image can be seen while the film is still wet. This action is accompanied by certain dimensional changes in the image which in the literature go by the name of the Ross effect, and which, in many cases, introduce distortion in sound recorded on film. Have any observations been made as to the magnitude of the Ross effect in the vanadium development?

Mr. Rasch: We haven't made any specific investigations of that effect but the sound-track quality for variable-area sound is at least equal to that of conventional processing. From the standpoint of variable-density recording, higher intermodulation distortion levels were found.

Tom Hill (Ringwood Chemical Corp., Ringwood, Ill.): What provisions or plans have been made for neutralizing or removing from the premises the by-product bromine gas?

Mr. Rasch: The amount of bromine gas coming off was extremely small and we could get rid of it by turning it into the regular flues of the Research Laboratories. However, we have run tests in which a hydrobromic acid solution was used as the anolyte and in that case we get a much greater volume of bromine gas. However, bromine gas is absorbed very readily in a sodium carbonate solution with the release of carbon dioxide.

A Mathematical Approach to Replenishment Techniques

By SAMUEL R. GOLDWASSER

Equations are derived for use in calculating formulas and rates of addition of replenisher solutions. Replenishment formulas and rates are determined not only by chemical reactions between constituents of the film and the solutions, but also by physical characteristics of the equipment in which the film is processed. When values for carry-over, tank volume, overflow, film velocity-chemical activity, and concentration levels are inserted in appropriate equations, replenisher formulas and rates can be calculated. The application of the equations to a typical problem is shown.

In processing motion-picture film, it is common practice to renew solutions in the developing machines by the use of replenishment systems. Physical and chemical changes take place in the various solutions as film is processed, and the used solutions, instead of being discarded, are replenished continuously and automatically. The replenishers balance out changes occurring in the solutions which would affect sensitometric properties of the film. In black-and-white systems, each developer and hypo solution is generally replenished, while in color systems each developer, hypo, prebath, short-stop, bleach and stabilizer solution is likely to be replenished.

Presented on October 6, 1953, at the Society's Convention at New York by Samuel R. Goldwasser, Laboratory Branch, Signal Corps Pictorial Center, Long Island City 1, N.Y.
(This paper was received October 6, 1953.)

Studies of replenishment technique in the past have been devoted primarily to developer solutions. The emphasis on developer solutions arose because small changes in composition of the developer affect the gamma and density of film markedly, while small variations in composition of the other solutions do not appear to exert such conspicuous and measurable effects. Although deviation of a nondeveloper solution from its original formula may show no immediate effect, such variation has been known to cause blurring of images and fading of colors after passage of time.

Past replenishment studies narrowed themselves to developer solutions used in certain limited ways. Film is generally dry, in black-and-white systems, as it enters the developer, and previous replenishment techniques have therefore been concerned primarily with tanks where no liquid was carried into the solution by the film. Color film,

SYMBOLS

Symbol	Definition	Units
A	Rate of carry-over of liquid into tank	Gallons per foot
B	Rate of loss of solution from tank	Gallons per foot
B_c	Rate of loss of solution from tank by carry-over	Gallons per foot
B_o	Rate of loss of solution from tank by overflow	Gallons per foot
C	Concentration	Grams per liter
C_o	Desired concentration of constituent in processing solution	Grams per liter
C_r	Concentration of constituent in replenisher solution	Grams per liter
$+D$	Rate of removal of constituent from solution due to chemical reaction	Grams per foot
$-D$	Rate of addition of constituent to solution due to chemical reaction	Grams per foot
f	Quantity of leader or film	Feet
R	Rate of addition of replenisher solution	Milliliters per minute
T	Tank capacity	Gallons
V	Rate of passage of film through machine	Feet per minute
W	Quantity of constituent in tank	Grams
W_o	Initial quantity of constituent in tank	Grams
W_r	Quantity of constituent in replenisher	Grams

however, is often wet when it reaches the developer, and the amount of liquid carried in by the entering film does affect the formulation of the replenisher and the rate at which it should be pumped into the developer tank.

Empirical methods have generally been used in establishing replenishment formulas and rates. In commenting on a paper by Evans[1] dealing with calculation of developer concentrations, Townsley[2] reported that the "cut and try" method of establishing a replenishment technique had worked well in his laboratory. Townsley indicated that over 25,000 ft of 16mm film had been processed weekly for 18 months, and required no adjustments in developing time or replenishment rate. Baumbach[3] described replenishment techniques which had also proved quite workable. He reported that occasionally, in an unpredictable way, processing solutions strayed from the desired concentration levels, so that they had to be readjusted. Baumbach also indicated that close sensitometric and chemical control had to be employed in order to detect trends away from gamma and density standards. Bates and Runyan[4] described replenishment techniques which "were formulated using solution-analysis techniques" and proved successful "when used in combination with photographic and analysis tests." The schedule of analyses listed by Bates and Runyan included sensitometric tests every 15 min; temperature and *pH* checks every hour; bromide analyses every 4 hr; ferrocyanide analyses, specific gravity and silver analyses every 8 hr; and complete developer analyses every 48 hr.

Empirical methods have proved unsuccessful in some respects. A replenishment technique developed empirically will always work well for the particular operating conditions under which it was developed. When small changes in operating procedure, such as a readjustment of machine speed, are made, uncertainty about the effects makes it necessary to follow closely with control tests. New situations, such as a change from original negative to dupe negative, require that the trial-and-error process of finding a new replenishment rate start again right from the beginning. Also, empirical methods tend to be costly. As long as the desired results are gained, attention is given to expense in only a secondary way. Because the main object is to produce film meeting quality standards, and because silver recovery provides substantial returns, expenditures for raw materials are regarded as of minor importance. Consequently, a replenishment system which consumes tremendous quantities of chemicals and requires extensive control testing is considered, nevertheless, successful as long as film which satisfies quality requirements is produced. In an effort to deal with the problem of quality control without resorting to excessive use of chemicals or labor, the problem of replenishment is approached here by analyzing the process in terms of the basic factors involved.

Chemicals lost from processing solutions as film is processed must be replaced by the replenishers at the same rate at which they are lost. Similarly, those gained during processing must concurrently be eliminated, through the action of the replenishers. Carry-over of liquid by the film, and reaction between film and solution chemicals, cause the main changes in composition of the processing solutions. If rates of carry-over and reaction in a system are known, then it is a simple matter to calculate the replenishment that a system demands. These rates cannot always be measured directly, but equations can be formulated which express them in terms of measurable quantities. The first portion of this paper deals with the methods of determining rates of carry-over and reaction, while the latter portion shows how these values may be applied in calculating replenishment rates and formulas.

Determination of Carry-Over Rates

When wet leader enters and passes through a solution, the concentration of each chemical in the solution becomes reduced, even though no chemical reactions occur. Water carried in by the leader dilutes the solution, while liquid carried out by the leader withdraws chemicals from the solution. If the symbol W represents quantity of a constituent in a tank, and if f represents the number of feet of leader entering and leaving the tank, then the derivative dW/df represents the rate of loss of constituent from the tank. A constituent removed from a tank by carry-over is lost at a rate equal to the product of the rate of loss of liquid from the tank (B) and the concentration of the constituent at that particular time. It is possible to express concentration in terms of quantity of constituent (W) and volume of liquid in the tank. How much liquid is present in a tank after f ft of leader have passed through it? This volume is determined by the volume of liquid in the tank initially (T), the carry-over of liquid into the tank (Af), and the loss of liquid from the tank by carry-over at the exit (Bf). When concentration is expressed by the equivalent term, the following differential equation[5] may be set up to describe the rate of loss of a constituent from a tank as a result of carry-over:

$$\frac{dW}{df} = \frac{-W}{T + (A - B)f} B \qquad (1)$$

Equation 1 may be solved in the following way[5]:

$$\frac{dW}{W} = \frac{-B\,df}{T + (A - B)f} \qquad (2)$$

$$\ln \frac{W}{W_0} = \frac{-B}{A - B} \ln \frac{T + (A - B)f}{T} \qquad (3)$$

$$\frac{W}{W_0} = \left[\frac{T}{T + (A - B)f}\right]^{\frac{B}{A-B}} \qquad (4)$$

$$\frac{C}{C_0} = \left[\frac{T}{T + (A - B)f}\right]^{\frac{A}{A-B}} \qquad (5)$$

Although a complex relationship, involving an exponential term, exists between carry-over and concentration, simpler expressions can be deduced for systems common in motion-picture developing machines. In some tanks, the leader is dry when it enters, so that the carry-in rate, A, is zero. It is evident that in such tanks the concentration remains constantly at C_o. In other tanks of processing machines, the rate at which water is introduced into the tank by carry-over is equal to the rate at which solution is removed from the tank (i.e., A is equal to B). A differential equation may be set up describing this condition, and solved as follows:

$$\frac{dW}{df} = \frac{-WB}{T} \tag{6}$$

$$\frac{dW}{W} = \frac{-B\,df}{T} \tag{7}$$

$$\ln\frac{W}{W_o} = \frac{-Bf}{T} \tag{8}$$

$$\frac{W}{W_o} = e^{\frac{-Bf}{T}} \tag{9}$$

$$\frac{C}{C_o} = e^{\frac{-Bf}{T}} = e^{\frac{-Af}{T}} \tag{10}$$

This equation applies as long as the carry-over rate at the entrance is at least equal to the carry-over rate at the exit. The carry-in rate and carry-out rate are equal, for example, when rollers at the entrance and exit ends of a tank are positioned at the same height, and no hardening action takes place in the tank. The carry-in rate exceeds the carry-out rate when, for example, a tank is equipped with a squeegee at the exit end, but not at the entrance. Liquid then overflows from the tank, and despite the difference in carry-over rates, the rates of loss and gain of liquid nevertheless remain equal, so that the equation still applies. Figure 1 summarizes the relations between concentration, carry-over rates, tank volume, and footage for the different tanks. Sodium sulfate, sodium acetate and glycerol may be cited as examples of chemicals depleted by film primarily because of carry-over.

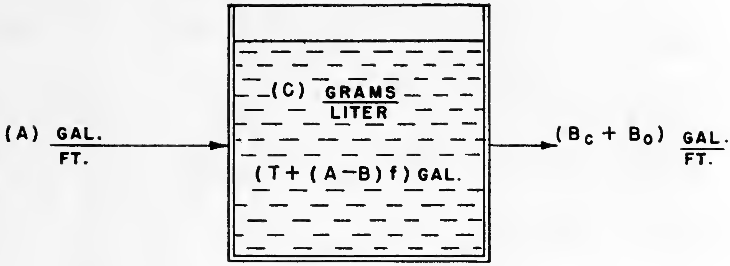
Before replenisher formulas and rates can be calculated, values of carry-in (A) and carry-out (B) rates must be obtained. Only the simplest methods of determining carry-over rates are mentioned here, but more involved methods may prove more precise. A measured quantity of film is first passed through the machine. If the volume of solution in the tank changes, measurement of the drop in level of the solution or the amount of liquid needed to maintain a constant level will indicate the net liquid loss. Also, both before and after the film is passed through, the solution is analyzed for one of the nonreactive constituents. The value of A, for the general type of tank, may then be calculated when these figures are substituted in Eq. (5), expressed in the form:

$$A = \frac{\text{Volume Change}}{f} \times \frac{\log C_o - \log C}{\log T - \log(T - \text{Volume Change})} \tag{11}$$

The volume reduction per unit length of film represents the difference between carry-in (A) and carry-out (B) rates. In tanks where the film is dry at the entrance, A is zero, and B therefore is equal to the volume loss divided by the quantity of film. In those tanks where the liquid level remains constant, values of A and B can be calculated from Eq. (10) expressed in the form:

$$A = B = \frac{T}{f}\ln\frac{C_o}{C} \tag{12}$$

If the solution overflows, then the liquid loss rate (B) calculated from this equation includes both the carry-over rate at the exit (B_e) and the overflow rate (B_o). Since the overflow can be readily collected and measured, the value of overflow per foot of film can be calculated. The difference between carry-in and overflow rates indicates the carry-out rate. Most machines are operated over a range of speeds, and so values of



Equation I: (General) $A = \dfrac{\text{Volume Change}}{f} \cdot \dfrac{\log C_o - \log C}{\log T - \log (T - \text{Volume Change})}$

$$\frac{C}{C_o} = \left[\frac{T}{T + (A - B)f}\right]^{\frac{A}{A-B}}$$

Equation II: $(A = O)$

$$B = \frac{\text{Volume Change}}{f}$$

$$\frac{C}{C_o} = 1$$

Equation III: $(A = B)$

$$A = \frac{T}{f} \ln \frac{C_o}{C} = B$$

$$\frac{C}{C_o} = e^{\frac{-Af}{T}}$$

Fig. 1. Concentration of a constituent after passage of leader.

A and B should be determined for several speeds.

Determination of Reaction Rates (Chemicals Consumed)

Chemical reactions between constituents of the film and solutions also change concentrations. Elon, sodium thiosulfate and potassium ferricyanide may be cited as some of the chemicals which are consumed in chemical reaction with constituents of the film. Although such chemicals react in complex ways, the quantity of each constituent which a foot of film removes tends to assume an average value. Since the rate of removal of a constituent by chemical action can be considered constant, a symbol (D) serves to indicate the amount of a chemical consumed by a unit quantity of film. When the rate of loss caused by chemical action is added to that caused by carry-over, an expression is obtained which describes the rate of loss resulting from the combined effects:

$$\frac{dW}{df} = \frac{-WB}{T + (A - B)f} - D \qquad (13)$$

This equation may be solved as follows:

$$\frac{dW}{df} + \frac{B}{T + (A - B)f} W = -D \qquad (14)$$

$$(T + (A - B)f)^{\frac{B}{A-B}} W = \int (-D)(T + (A - B)f)^{\frac{B}{A-B}} df \qquad (15)$$

$$(T + (A - B)f)^{\frac{B}{A-B}} W = \frac{-D}{A}(T + (A - B)f)^{\frac{A}{A-B}} + K \qquad (16)$$

$$(T + (A - B)f)^{\frac{B}{A-B}} W = \frac{-D}{A}(T + (A - B)f)^{\frac{A}{A-B}} + T^{\frac{B}{A-B}} W_o + \frac{D}{A} T^{\frac{A}{A-B}} \qquad (17)$$

$$(T + (A - B)f)^{\frac{A}{A-B}}C =$$

$$\frac{-D}{A}(T + (A - B)f)^{\frac{A}{A-B}} + T^{\frac{A}{A-B}}C_o + \frac{D}{A}T^{\frac{A}{A-B}} \tag{18}$$

$$C = \frac{-D}{A} + \left(C_o + \frac{D}{A}\right) \times \left(\frac{T}{T + (A - B)f}\right)^{\frac{A}{A-B}} \tag{19}$$

When solved for D, this equation then appears as:

$$D = A\frac{C_o T^{\frac{A}{A-B}} - C(T + (A - B)f)^{\frac{A}{A-B}}}{(T + (A - B)f)^{\frac{A}{A-B}} - T^{\frac{A}{A-B}}} \tag{20}$$

In tanks where the film is dry when it enters, the differential equation takes the form:

$$\frac{dW}{df} = \frac{-WB}{T - Bf} - D \tag{21}$$

This may be solved as follows:

$$\frac{dW}{df} + \frac{B}{T - Bf}W = -D \tag{22}$$

$$\frac{W}{T - Bf} = \int \frac{-D}{T - Bf}df \tag{23}$$

$$\frac{W}{T - Bf} = \frac{D}{B}\ln\frac{T - Bf}{T} + \frac{W_o}{T} \tag{24}$$

$$C = C_o - \frac{D}{B}\ln\frac{T}{T - Bf} \tag{25}$$

When solved for D, the equation then appears as:

$$D = \frac{B(C_o - C)}{\ln T - \ln(T - Bf)} \tag{26}$$

In those tanks where the rate of gain of liquid exactly equals the rate of loss of solution (so that $A = B$), the differential equation is:

$$\frac{dW}{df} = \frac{-WB}{T} - D \tag{27}$$

and may be solved by the following steps:

$$\frac{dW}{WB + TD} = \frac{-df}{T} \tag{28}$$

$$\frac{1}{B}\ln\frac{WB + TD}{W_oB + TD} = \frac{-f}{T} \tag{29}$$

$$C = \frac{W}{T} = e^{\frac{-Bf}{T}}\left(C_o + \frac{D}{B}\right) - \frac{D}{B} \tag{30}$$

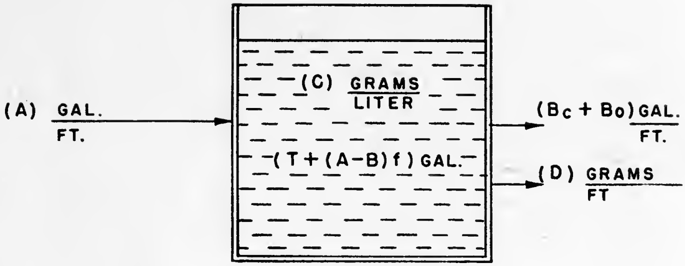
Or when solved for D, this equation is expressed as:

$$D = B\,(C_oe^{\frac{-Bf}{T}} - C)(1 - e^{\frac{-Bf}{T}})^{-1} \tag{31}$$

Values of D may be obtained by methods similar to those used in determining A and B. The solution is analyzed for a constituent, both before and after a known amount of film is processed. Values of tank volume (V), concentration (C and C_o), footage (f), carry-in rate (A), and carry-out rate (B) are then substituted in the appropriate equation—whichever one applies for the particular tank—and the equation is solved for D. A summary of the equations which may be used in calculating D for this type of chemical is listed in Fig. 2.

Determination of Reaction Rates (Chemicals Added)

When film passes through processing solutions, certain constituents are added to the solutions, rather than withdrawn, as a result of chemical action. Potassium bromide, silver thiosulfate, and potassium ferrocyanide are the most prominent examples of the chemicals showing this type of behavior. The differential equations for such constituents may be set up, and solved, in the same way as for constituents depleted by chemical action, except that in this case D may be considered to have a negative sign. Values of D for these



Equation IV: (General)

$$D = (-A)\frac{\left(C_o T^{\frac{A}{A-B}} - C(T+(A-B)f)^{\frac{A}{A-B}}\right)}{\left(T^{\frac{A}{A-B}} - (T+(A-B)f)^{\frac{A}{A-B}}\right)}$$

$$C = \frac{-D}{A} + \left(C_o + \frac{D}{A}\right)\left(\frac{T}{T+(A-B)f}\right)^{\frac{A}{A-B}}$$

Equation V: $(A = O)$

$$D = B\,\frac{(C_o - C)}{\ln T - \ln(T - Bf)}$$

$$C = C_o - \frac{D}{B}\ln\frac{T}{T-Bf}$$

Equation VI: $(A = B_c)$

$$D = A\left(C_o e^{\frac{-Af}{T}} - C\right)\left(1 - e^{\frac{-Af}{T}}\right)^{-1}$$

$$C = e^{\frac{-Af}{T}}\left(C_o + \frac{D}{A}\right) - \frac{D}{A}$$

Fig. 2. Concentration of a constituent after passage of film. Constituent is depleted by chemical reaction and by carry-over.

constituents may be calculated from the equations listed in Fig. 3.

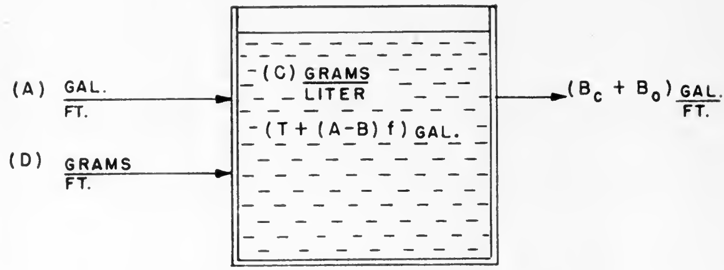
Calculation of Replenishment Rates and Formulas

Processing solutions that are maintained constantly at the concentration values of the original formula—or a "seasoned solution" formula—can be expected to produce film of unchanging photographic qualities. The ideal replenishment system will constantly counterbalance dilution and contamination effects of film, and thereby continuously restore constituents of the processing solutions to concentrations of the basic formula. A chemical removed from the solution by carry-over, overflow or chemical action must be supplied by the replenisher at the same rate at which it is lost; a chemical added to the solution as a result of film passage must be removed by replenishment action at the rate at which it tends to build up. The equality which should exist between the replenishment rate and the exhaustion rate may be expressed mathematically. If the weight of chemical in a tank at any time is W, film footage is f, velocity of film passage is V, concentration of chemical in replenisher is C_r, and rate (in time) of addition of the replenisher solution is R, then:

$$C_r R = -\frac{dW}{df}V \qquad (32)$$

The term dW/df must now be evaluated.

The rate of loss, and therefore the rate of replenishment, of a nonreactive constituent depends on concentration of the chemical and on rate of removal of the liquid from the tank. It was shown previously that the rate at which a nonreactive chemical is lost can be expressed by the following equation:



Equation VII: (General)

$$D = (A)\frac{\left(C_oT^{\frac{A}{A-B}} - C(T+(A-B)f)^{\frac{A}{A-B}}\right)}{\left(T^{\frac{A}{A-B}} - (T+(A-B)f)^{\frac{A}{A-B}}\right)}$$

$$C = \frac{D}{A} + \left(C_o - \frac{D}{A}\right)\left(\frac{T}{T+(A-B)f}\right)^{\frac{A}{A-B}}$$

Equation VIII: $(A = O)$

$$D = B\frac{(C - C_o)}{\ln T - \ln(T - Bf)}$$

$$C = C_o + \frac{D}{B}\ln\frac{T}{T - Bf}$$

Equation IX: $(A = B)$

$$D = A\left(C - C_oe^{\frac{-Af}{T}}\right)\left(1 - e^{\frac{-Af}{T}}\right)^{-1}$$

$$C = e^{\frac{-Af}{T}}\left(C_o - \frac{D}{A}\right) + \frac{D}{A}$$

Fig. 3. Concentration of a constituent after passage of film. Constituent is added to solution by film and is depleted by carry-over.

$$\frac{dW}{df} = \frac{-WB}{T + (A - B)f} \qquad (33)$$

in which A is the volume of liquid carried into the tank per foot of film, B is the volume of solution carried out of the tank per foot, and T is the initial volume. In continuous replenishment, only an infinitesimal change of concentration or volume should occur before the replenisher restores the solution to its original condition. The value of $\frac{W}{T + (A - B)f}$ therefore centers about C_o, and consequently:

$$C_rR = BC_oV \qquad (34)$$

It is also possible to derive Eq. (34) by starting with the differential equation:

$$\frac{dW}{df} = \frac{C_rR}{V} - \frac{WB}{T + \left(\frac{R}{V} + A - B\right)f} = 0$$

and then substituting C_o for the term $\frac{W}{T + \left(\frac{R}{V} + A - B\right)f}$.

The constant B, representing the total amount of solution lost from the tank as one foot of film passes through, includes the solution carried out by the film (B_c) as well as the solution overflowing from the tank (B_o). The rate of overflow is determined not only by the carry-over at the entrance (A) and the exit (B_c) but also by the rate of addition of the replenisher solution (R). As long as the solution in the tank is maintained at the same level, the rates of admission and removal of liquid are equal, and the following equality may therefore be expressed:

$$R + AV = BV = (B_c + B_o)V \quad (35)$$

where R indicates volume of replenisher solution added per unit of time. The replenisher equation may now be rewritten with the $B \cdot V$ term replaced:

$$C_rR = C_oBV = C_o(B_c + B_o)V = C_oR + C_oAV \quad (36)$$

When a constituent is involved in chemical reactions as the film is processed, it must be replenished in a way to compensate not only for the losses due to carry-over but also for the losses (or gains) due to chemical reaction. As shown previously, the rate at which chemical is removed from a tank by both carry-over and reaction may be expressed by:

$$\frac{dW}{df} = \frac{-WB}{T + (A - B)f} - D \quad (37)$$

Here, too, because continuous replenishment is used, the concentration value can be approximated:

$$C_o = \frac{W}{T + (A - B)f} \quad (38)$$

Consequently,

$$\frac{dW}{df} = -(BC_o + D) \quad (39)$$

and

$$C_rR = V(BC_o + D) = C_oR + C_oAV + DV \quad (40)$$

Where a chemical is added to the solution as a consequence of film passage, the DV term is subtracted, rather than added.

The complete replenisher formula can be calculated from the above equations after a replenishment rate (R) is established. The rate of replenishing is closely related to the rate of loss of solution overflowing from the tank. Although overflow solution is constituted in the proportions of the processing formula and contains unreacted chemicals, it generally is discarded. Losses of chemicals down the drain as a result of overflow can be minimized, therefore, by choosing as small a value of R as possible. Three factors limit the minimum value which may be chosen for R:

(1) Enough liquid must be supplied to maintain the solution at the top level of the tank. The replenisher must compensate for the water losses just as for the chemical losses, and where carry-over at the exit exceeds carry-over at the entrance, replenishment must supply the additional liquid. This requirement may be expressed by the equation:

$$R \geq (B_c - A)V \quad (41)$$

(2) Enough liquid must be supplied to dissolve all solids in the replenisher. If the replenisher must supply large quantities of a relatively insoluble chemical, the replenisher must then also contain a large amount of water, in order that the constituent will be completely dissolved. The replenishment rate may be expressed, as Eq. (40) shows, in terms of the various other factors:

$$R = \frac{C_oAV + DV}{C_r - C_o} \quad (42)$$

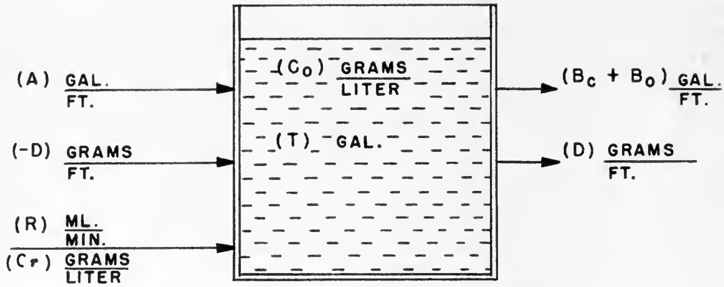
If the constituent is contained in the replenisher at its solubility limit (C_s), the minimum replenishment rate, based on solubility, would be:

$$R \geq \frac{C_oAV + DV}{C_s - C_o} \quad (43)$$

(3) Enough liquid must be supplied to minimize effects of constituents which are added to the solution as film is processed. Certain of the substances which tend to increase in concentration exert marked effects on sensitometric properties of the film. Replenisher solution must be added at a sufficiently rapid rate to dilute the solution, maintaining these constituents at a constant concentration level. When such a constituent is omitted completely from the replenisher, the minimum replenishment rate, as derived from Eq. (40), is:

$$R \geq \frac{-DV}{C_o} - AV \quad (44)$$

The replenishment rate is usually deter-



Equation X:

$$C_r = \frac{(B_c + B_o)C_oV + D\cdot V}{R}$$

$$C_r = \frac{(AV + R)C_o + D\cdot V}{R}$$

$$C_r = \frac{AVC_o + D\cdot V}{R} + C_o$$

Equation XI: $R \geq (B_c - A)V$

Equation XII: $$R \geq \frac{C_o\,VA + D\cdot V}{C_s - C_o}$$

Equation XIII: $$R \geq \frac{-D\cdot V}{C_o} - AV$$

Fig. 4. Equations for calculating replenisher formulas and rates.

mined in developer solutions by the build-up of potassium bromide; in hypo solutions by the formation of silver thiosulfate; and in bleach solutions by the increased ferrocyanide content. Figure 4 summarizes the replenisher equations.

Intermittent Replenishment

Some solutions may be replenished by adding the chemicals periodically in bulk quantities, rather than by supplying them continuously, in infinitesimal amounts. An intermittent replenishment procedure may be employed where wide concentration ranges can be tolerated and where the constituents will dissolve readily. If W_o is the initial quantity of constituent in the tank, and W is the amount of chemical in the tank after f ft of film has passed, then the following equation expresses the amount of constituent (W_r) which must be supplied by the replenisher at each interval:

$$W_r = W_o - W \qquad (45)$$

Equations (17), (24) and (30) show that W can be evaluated, for each of the three types of tanks, in terms of footage, tank volume, carry-over rates and reaction rates. Consequently the quantity W_r can also be expressed in terms of these measurable quantities. When this substitution is made, it is found that, for the general type of tank, the replenisher should contain the following amount of each nonreactive constituent:

$$W_r = W_o\left(1 - \left(\frac{T}{T + (A - B)f}\right)^{\frac{B}{A-B}}\right) \qquad (46)$$

Where a constituent is consumed by chemical action, the replenisher must also contain the additional quantity:

$$\frac{D}{A}\left(T + (A - B)f - \frac{T^{\frac{A}{A-B}}}{(T + (A - B)f)^{\frac{B}{A-B}}}\right) \qquad (47)$$

In tanks where no carry-in occurs, the replenisher should contain the following amount of each chemical:

$$W_r = W_o\frac{Bf}{T} + D\left(\frac{T}{B} - f\right)\ln\frac{T}{T - Bf} \qquad (48)$$

The latter term, involving D, obviously disappears for nonreactive constituents. In tanks where the rates of gain and loss of liquid are equal, the quantity of constituent in the replenisher should be:

$$W_r = W_o(1 - e^{\frac{-Bf}{T}}) + \frac{TD}{B}(1 - e^{\frac{-Bf}{T}}) \quad (49)$$

Daily replenishment of such solutions as the glycerine stabilizer is often accomplished on the basis of this equation.

New Operating Conditions

A developing machine generally is not operated week after week at the same speed, nor are developing machines expected to process exclusively only one kind of film emulsion, film type or film size. A particular replenishment rate and formula calculated from Eq. (40) constitute optimum values for only one particular machine velocity and film; other conditions require other rates and formulas. It is impractical to change the formulation of the replenisher solution frequently, but if the replenishment rate is adjusted appropriately for each situation, the same replenisher formula may serve satisfactorily for all conditions. Expressions can be readily derived from Eq. (40) to describe the replenishment rate for a new condition, on the basis of the original replenishment rate and the parameters of the original and the new condition:

(1) When machine speed is changed, the new replenishment rate can be calculated from:

$$R = \frac{R_oV}{V_o} \cdot \frac{C_oA + D}{C_oA_o + D} \cong \frac{R_oV}{V_o} \quad (50)$$

The symbols A_o, V_o and R_o represent values obtained at the original machine speed. The replenishment rate should evidently vary in about the same proportion as the machine velocity.

(2) When type, or average density, of film is changed, the new replenishment rate should be:

$$R = R_o \frac{C_oA + D}{C_oA_o + D_o} \quad (51)$$

Values of A_o and D_o are obtained from the original film type or film density. The most critical constituent determines the values assigned for C_o, D_o and D.

(3) When leader, rather than film, is run through the machine, the replenishment rate should be:

$$R = R_o \frac{C_oA}{C_oA_o + D} \quad (52)$$

Here, too, C_o and D are based on the most critical constituent. A tank which receives dry leader would require, according to the above equation, a replenishment rate of zero. No water is brought in by the leader, and solution lost by carry-over at the exit must obviously be replaced. In this special case, replenishment can be accomplished with a solution compounded from the basic—not the replenisher—formula.

Illustration

An example will demonstrate how the replenisher equations can be used in calculating replenisher formulas and rates.

A processing solution is prepared according to the following specification:

$$X = 60 \text{ g/l}$$
$$Y = 60 \text{ g/l}$$
$$Z = 4.00 \text{ g/l}$$

Component X does not react; component Y is consumed at the rate of 15 g/1000 ft; component Z, which must be held within the narrowest concentration range, is formed at the rate of 10 g/1000 ft. The carry-in rate is 0.15 gal/1000 ft and the carry-out rate is 0.25 gal/1000 ft. The film travels through the machine at 70 fpm. Solubility of X is 200 g/l; of Y is 140 g/l; and of Z is 10 g/l. What should the replenishment rate and formula be?

Calculations: The minimum value of R is determined:

$$R \geq V(B_c - A) \qquad (53)$$

$$\geq \frac{(70)\ \text{ft}}{\text{min}} \frac{(0.25\ -0.15)}{(1000)} \frac{\text{gal}}{\text{ft}} (3785) \frac{\text{ml}}{\text{gal}} \qquad (54)$$

$$\geq 26.5\ \frac{\text{ml}}{\text{min}} \qquad (55)$$

$$R \geq \frac{(C_oA + D)V}{C_s - C_o} \qquad (56)$$

$$\geq \frac{(60) \frac{\text{gram}}{\text{liter}} \frac{(0.15)}{(1000)} \frac{\text{gal}}{\text{ft}} (3.785) \frac{\text{liter}}{\text{gal}} + \frac{(15)}{(1000)} \frac{\text{gram}}{\text{ft}}}{(140 - 60) \frac{\text{gram}}{\text{liter}} \frac{(1)}{(1000)} \frac{\text{liter}}{\text{ml}}} (70) \frac{\text{ft}}{\text{min}} \qquad (57)$$

$$\geq 42.9 \frac{\text{ml}}{\text{min}} \qquad (58)$$

$$R \geq \frac{-DV}{C_o} - AV \qquad (59)$$

$$\geq \frac{\frac{(10)}{(1000)} \frac{\text{gram}}{\text{ft}} (70) \frac{\text{ft}}{\text{min}} (1000) \frac{\text{ml}}{\text{liter}}}{(4) \frac{\text{gram}}{\text{liter}}} - \frac{(0.15)}{(1000)} \frac{\text{gal}}{\text{ft}} (3785) \frac{\text{ml}}{\text{gal}} (70) \frac{\text{ft}}{\text{min}} \qquad (60)$$

$$= 135 \frac{\text{ml}}{\text{min}} \qquad (61)$$

The replenishment rate should therefore be 135 ml per minute.

Replenisher concentrations may now be calculated:

$$C_r = \frac{C_o(AV + R) + DV}{R} = C_o + \frac{C_oAV + DV}{R} \qquad (62)$$

$$C_r = C_o + \frac{(C_o) \frac{\text{g}}{\text{l}} \frac{(0.15)}{(1000)} \frac{\text{gal}}{\text{ft}} (70) \frac{\text{ft}}{\text{min}} (3785) \frac{\text{ml}}{\text{gal}}}{(135) \frac{\text{ml}}{\text{min}}} + \frac{(D) \frac{\text{g}}{\text{ft}} (70) \frac{\text{ft}}{\text{min}} (1000) \frac{\text{ml}}{\text{l}}}{(135) \frac{\text{ml}}{\text{min}}} \qquad (63)$$

$$C_r = C_o + C_o(0.295) + D(519) \qquad (64)$$

	X	Y	Z
C_o	60 g/l	60 g/l	4 g/l
$C_o(0.295)$	17.7	17.7	1.18
$D(519)$	0	7.8	−5.19
C_r	77.7	85.5	0

Conclusion

Formulas and rates for continuous replenishment, and for intermittent replenishment, of solutions in developer machines can be established by methods presented here. Tank size, machine velocity, carry-over of liquid on the film, concentration values, and chemical reactions between film and solution have been shown to determine optimum replenishment formulas and rates. These controlling factors have been incorporated in equations, so that replenisher formulas and rates can be calculated readily when values of these factors are known. By means of this mathematical approach, it is believed that variation in film density and gamma caused by changes in processing solutions can be appreciably reduced, and that a savings in certain operating expenses can be attained.

References

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3. H. L. Baumbach, "Continuous replenishment and chemical control of motion picture developing solutions," *Jour. SMPE, 39:* 55–66, July 1942.

4. J. E. Bates and I. V. Runyan, "Processing control procedures for Ansco Color Film," *Jour. SMPE, 53:* pp. 3–24, July 1949.
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Discussion

J. I. Crabtree (Kodak Research Laboratories): It isn't quite clear how you calculate the amount of developing agent in the replenisher necessary to overcome the restraining action of the bromide, iodide, hydroquinone sulfonates, etc., in the exhausted developer. Secondly, how closely are your calculations correlated with practice?

Mr. Goldwasser: Gamma and density values in a seasoned solution often differ from those of the original solution because of the restraining action of products formed in development, even though the routine chemical analysis may show no difference. One way of counterbalancing the restraining effect of these products is to change the basic formula of the processing solution, for example, by raising the concentration of the developing agent (which Mr. Crabtree suggests) or by lowering the level of the bromide or iodide content. Another approach is to increase the replenishment rate above that calculated from Eq. 13 in order to hold down the concentration of these substances. I doubt whether the adjustment Mr. Crabtree speaks of can be calculated, unless it were readily possible to measure concentration values, reaction rate values, and sensitometric effects of each of the restraining products. It seems better to handle such second-order and third-order effects in an empirical manner. One can expect mathematics to bring one within the range of the optimum replenishment conditions; one cannot expect such an approach to make it possible to dispense with experimentation, sensitometric control or chemical control.

To answer the second question, experimental work is still in progress; results are not yet available.

Mr. Crabtree: That is the trouble in photography. There are so many factors involved that you cannot predict anything, precisely. The only answer is to "try it." It takes many, many years before you realize that fact.

The Effect of Camera Exposure on the Tone-Reproduction Quality of Motion Pictures

By ALLAN L. SOREM

A psychophysical study has been made of the relationship between the tone-reproduction quality of a positive motion-picture screen image and the camera exposure for the corresponding negative throughout a series of negative exposures for each of sixteen outdoor scenes and eight indoor scenes. A description is given of the method used for obtaining psychometric data, and curves are presented showing the relationship between screen image quality and the logarithm of the camera exposure. The use of these curves in determining exposure latitude, speed and exposure index is discussed.

The evaluation of a photographic material from the standpoint of its ability to perform the function for which it is intended is very often based upon a study of the characteristic *D*-log *E* curve of the material. Methods of interpreting characteristic curves have been the subject of many studies and experiments in the field of photographic sensitometry, having the common objective of increasing the yield of significant information about the photographic properties of the materials which they represent. In the field of black-and-white still photography, for example, methods have been developed for obtaining and interpreting the characteristic curves of both negative films and positive reflection print materials, which permit an accurate evaluation of the photographic properties of these materials under the conditions in which they will be used in practice.

Communication No. 1617 from the Kodak Research Laboratories, by A. L. Sorem, Kodak Research Laboratories, Eastman Kodak Co., Rochester 4, N. Y. The paper was presented on October 8, 1953, at the Society's Convention at New York. (This paper was received Nov. 19, 1953.)

In pictorial photography, the final photographic image of whatever sort, black-and-white or color, reflection print or projected screen image, is but a means of producing in the mind of an observer a more or less accurate impression of the appearance of an original scene. Most physical measurements of the properties of photographic materials are fully significant only if one knows the manner in which the measured properties affect the ability of the material to produce a satisfactory impression in the mind of the observer. The sensitometrist is therefore obliged to extend his investigations outside the field of physics and into the realm of psychophysics, which deals with problems common to psychology and physics. The end product of most investigations in psychophysics is information concerning the relationship between some psychological or subjective variable and a physical or objective variable. The principles of psychophysics and its importance to photography have been thoroughly discussed by L. A. Jones,[1] who has done a great deal of pioneering work in psychophysics applied to photography.

The concept of the speed of a photographic material has inescapable psychophysical connotations. One material is usually regarded as having a higher speed than another when it will produce a satisfactory photographic image with less exposure. In order to place the concept of speed on a workable basis for black-and-white motion-picture negative films, however, a more explicit statement is required. Such a statement is the following, which is analogous to the statement regarding the concept of speed in the "American Standard Method for Determining Photographic Speed and Exposure Index," Z38.2.1-1947, applying to roll and sheet films: *The speed of a motion-picture negative film for continuous-tone black-and-white pictorial photography is inversely proportional to the minimum exposure required to produce a negative from which a positive print can be obtained that will give a projected screen image of high quality.* This definition represents a logical basis for a sensitometric speed criterion for motion-picture negative films. The necessary first step toward the realization of such a sensitometric criterion is a psychophysical study of the manner in which the quality of the projected positive screen image varies with the camera exposure given the negative.

A study has been completed using photographic reproductions of sixteen outdoor scenes and eight studio scenes. An exposure series was made of each scene on each of two black-and-white motion-picture negative materials. Exposure series of most of the outdoor scenes were also made on each of two reversal color films. The tone-reproduction quality of the final positive images obtained with each material was judged by about thirty observers. Averages of all of the judgments were obtained and used in plotting curves showing the tone-reproduction quality of the positive image as a function of the logarithm of the camera exposure.

Choice of Scenes

The scenes which were photographed were planned and constructed with two principal aims in mind. As far as possible, it was desired to conform to lighting practices followed in professional motion-picture work. It was also desired to have as much variety as possible in the types of scenes which were used. It was not difficult to meet both of these requirements for the studio scenes, but the outdoor scenes presented some problems in lighting which were caused by changes in the position of the sun during the time required to make all of the necessary exposures, meter readings and scene luminance measurements. The fill-in lighting required to reduce the ratio of highlight to shadow illumination on the models in the outdoor scenes was obtained by using reflectors. The lighting problem was somewhat simplified by the fact that the people in each scene remained motionless. Experience has shown that it is easier to evaluate the relative tone-reproduction quality of each scene in an exposure series if the people in the scene remain in one position throughout the series.

The hope has sometimes been expressed that an "average" scene could be set up which would be so nearly typical of the scene types encountered in motion-picture work that it could be used in making direct camera exposure tests, making unnecessary the considerable expenditure of time and effort required to carry out experiments involving many different scenes. There are several reasons why this is not feasible. The variables which change from scene to scene, and the combinations and interactions of these variables, are so numerous that it is practically impossible with any reasonable degree of certainty to isolate the significant variables for consideration. For example, although it is quite probable that the exposure required to produce optimum quality will depend upon the lighting ratio, the nature of this dependence will, in turn, be affected by the relative size and importance of shadow and highlight areas.

It is probably true, also, that most observers will not be equally critical of the tone-reproduction quality in every area of a positive reproduction. Unless the observers are exceedingly conscientious and painstaking, their attention will be directed critically only to the areas which constitute the center of interest in the scene, or, for more sophisticated observers, to those areas which they feel represent the best clues to tone-reproduction quality. Moreover, because of the limitations of the photographic process, a given exposure will not, in general, produce the optimum quality in all areas of the reproduction. This is particularly true if the latitude of the photographic material is short and the range of luminances of objects in the scene is long. If a color reproduction is being studied, these considerations must be further extended to include the variation in hue and saturation of differently colored objects as the exposure is changed. It is apparent that the use of a limited number of scenes, or of a single scene which is purported to be average, may result in serious systematic errors in determining the average relationship between the overall tone-reproduction quality of reproductions and the camera exposure for a given material.

The scenes which were used are illustrated in Figs. 3 through 8. The scene areas included in these illustrations are different in some cases from those in the motion-picture prints, and the tone-reproduction quality of the reproductions is, of course, not representative of that of the projected motion-picture prints. Twelve of the sixteen outdoor scenes included people at various distances from the camera. The subjects of three of the other scenes might be classed as architectural, and the fourth was a landscape. All outdoor scenes were photographed on cloudless or nearly cloudless days to insure that the lighting would remain as nearly constant as possible during the time required for making the photographs, reading exposure meters, and making photometric measurements.

All the eight indoor scenes included at least one person. For reasons previously given, none of these scenes is regarded as "average," but, taken as a group, they include characteristics which are found in many of the indoor scenes photographed in Hollywood. Scene 20 is the same as Scene 23, but it was reconstructed and lighted with normal lighting several weeks after Scene 23 had been photographed in low key with strong backlighting. A vivid illustration of the effect of lighting variables on the apparent quality characteristics of the two films is provided by this pair of scenes.

Light Measurements

Five different exposure-meter readings were made for each scene, as follows:

(1) An incident-light measurement was made with the meter at the subject position pointed at the camera.

(2) An incident-light measurement was made with the meter at the subject position pointed toward the sun, in the case of the outdoor scenes, and, for the indoor scenes, pointed in such a direction that the highest reading was obtained.

(3) A measurement was made of the light reflected from a gray card held in front of the subject's face, perpendicular to the subject-camera axis.

(4) A meter with hemisphere was read at the subject position, with the top of the hemisphere toward the camera.

(5) A reflected-light reading was made at the camera position.

Luminance measurements were made on several areas in each scene, using a Macbeth Illuminometer modified to read the luminance of a field subtending an angle of about 10 min. Photographs of the outdoor scenes were also made with a 5 × 7-in. camera on Kodak Super-XX Panchromatic Sheet Film which was processed with sensitometric strips exposed on an intensity-scale sensitometer, so that additional luminance values could be calculated by means of photographic photometry. The luminance measurements will be used in a future study of the tone-reproduction characteristics of high-quality black-and-white motion-picture prints. The various exposure-meter readings will be used in studying the correlation between optimum exposures and meter readings.

Photography

The indoor scenes were photographed on Eastman Background-X Panchromatic Negative Safety Film, Type 5230, and Eastman Plus-X Panchromatic Negative Safety Film, Type 5231, with a Mitchell camera running at 24 frames/sec, using either a Cooke Speed Panchro 50mm lens or a Bausch & Lomb Baltar 40mm lens. Seven exposures were usually made on each material, ranging from the equivalent of at least $1\frac{1}{2}$ stops over, to at least $1\frac{1}{2}$ stops under, the estimated optimum exposure for the scene. Thirty feet of film were exposed at each camera exposure setting. For the indoor scenes, the exposure variation was accomplished by changing the exposure time. The same combinations of aperture and exposure time were used for the two materials, and a neutral filter ($D = 0.43$) was placed in front of the lens when the faster material was being exposed.

The same camera was used in photographing the outdoor scenes, but the exposure variation within the series on each material was accomplished by changing the lens aperture. The exposure times for the two materials were different. Ideally, all of the changes in exposure should have been accomplished by changing the aperture of the taking lens, but the range of apertures available was not large enough to cover the required range of exposures. The intervals between successive exposures on each material averaged about $\frac{1}{2}$ stop.

Two additional exposure series were made of most of the outdoor scenes on Kodak Ektachrome Film, Daylight Type, and on Kodachrome Film, Daylight Type. The pictures from Ektachrome Film were made with a 5 × 7-in. camera having a calibrated shutter, from the same position as that occupied by the motion-picture camera, and using a lens giving approximately the same angular coverage as that of the motion-picture camera. The 35mm Kodachrome Film was exposed in a camera having a calibrated focal-plane shutter. The changes in exposure level for each series on the color films were made by changing the lens apertures of the cameras.

Sensitometric Exposures

Each series of exposures on the two motion-picture films was processed with sensitometric exposures made with an intensity-scale sensitometer. Sensitometric exposures were also made on each of the color materials and processed with each exposure series. A complete sensitometric record for each material is provided by these exposures.

Processing and Printing

The motion-picture negative films were processed to an average gamma of 0.65. By adjusting the printing exposure the best possible print was made on Eastman Fine Grain Release Positive Safety Film, Type 5302, from each of the negatives. The positive film was developed to a gamma of 2.6.

Densitometry

Density measurements were made of all areas in the negatives and prints corresponding to the areas for which luminance measurements had been made in the original scenes. Negative and positive step-tablet densities were also read. These data will be used in the

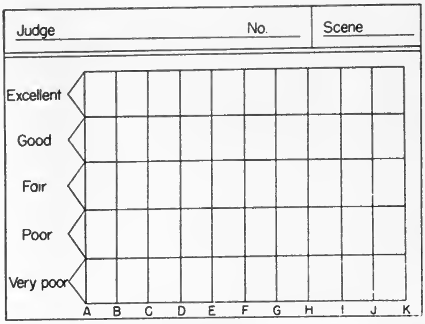

Fig. 1. Form on which observers recorded judgments of tone-reproduction quality.

study of the optimum tone-reproduction characteristics of motion-picture prints.

Judging

The prints were presented to an audience of observers in the auditorium of the Kodak Research Laboratories. A screen luminance of 10 ft-L was used. The indoor scenes were judged by 34 observers at the first viewing session, and the outdoor scenes by 32 observers at a later session. About half of the observers at each session can be classified as experts in the evaluation of tone-reproduction quality; 20% were persons with varying amounts of previous experience in making this type of judgment, who had some familiarity with the general procedure being followed; and the remaining 30% had had little or no previous experience.

Each observer was supplied with a number of forms for recording his judgments, as illustrated in Fig. 1. A separate sheet was used for each exposure series. There were 16 sheets to be filled out by each observer for the indoor scenes, and 32 sheets for the outdoor scenes. The quality scale shown at the left of the sheet is intended to embrace all levels of quality. It is divided into 5 categories: "excellent," "good," "fair," "poor" and "very poor." The observers were instructed to indicate their opinion of the quality of each scene at each exposure level by means of a short horizontal mark across the appropriate vertical line. Any number of different quality levels could be indicated within each of the labeled categories. For example, a judge might feel that all the prints of a particular exposure series were "good," although he would recognize that some were better than others. He would therefore make all of his marks at various levels within the "good" region. It can be seen that this method of recording the judgment data permits both an absolute rating of each picture according to five more or less arbitrary but mutually exclusive quality categories, as well as the rating of relative quality on a continuous scale.

The use of heavy black lines on the graphs and a very low level of general illumination made it possible for the observers to record their judgments without undue eyestrain, and without changing their level of brightness adaptation from that of the motion-picture screen.

When the indoor scenes were judged, each exposure series was presented for a preliminary viewing, after which it was presented again and the judgments were recorded. The reproductions at each exposure level remained on the screen for about 20 sec. When the outdoor scenes were presented, the preliminary viewing of the pictures from each exposure level lasted only 4 sec, and the final viewing 16 sec. It is felt that the latter procedure permitted a better overall evaluation of the quality of a particular series, while causing the observers less fatigue.

All the series were presented in the same order, ranging from prints made from overexposed negatives to those made from the negatives having the least exposure.

The exposure series on Kodachrome Film, Daylight Type, were judged by twenty observers, who used the form in Fig. 1 for recording their judgments.

The Kodachrome transparencies were projected, one at a time, with a Kodak Master Model Projector. The screen luminance was about 15 ft-L.

The Ektachrome transparencies were displayed on an illuminator having a viewing-panel luminance of 400 ft-L, in a normally lighted room, and were judged by fifteen observers, who again used the form shown in Fig. 1 for recording judgments.

Interpretation of Data

The present report is confined to a study of the curves in Figs. 3 through 8, which were derived from the judgment data, showing tone-reproduction quality as a function of the logarithm of the camera exposure. Camera exposure has been defined[2] as follows:

$$E_c = \frac{t}{f^2},$$

where E_c is camera exposure, t is time expressed in seconds, and f is the aperture ratio. Since f is dimensionless, camera exposure has the dimension of time and is expressed in seconds. A camera exposure of 1 sec can be obtained, for example, by exposing for 1 sec at $f/1$, 4 sec at $f/2$, 16 sec at $f/4$, etc.

The values of quality for each camera exposure were obtained from the judgment data by averaging the ordinates measured on the judges' sheets, and the curves in Figs. 3 through 8 were plotted. The materials represented by these curves are as follows:

A. Eastman Plus-X Panchromatic Negative Safety Film, Type 5231.
B. Eastman Background-X Panchromatic Negative Safety Film, Type 5230.
C. Kodachrome Film, Daylight Type.
D. Kodak Ektachrome Film, Daylight Type.

Figure 2 illustrates the measurements which were made on all the sets of curves, and which will be described below.

It presents two hypothetical curves showing the relationship between quality

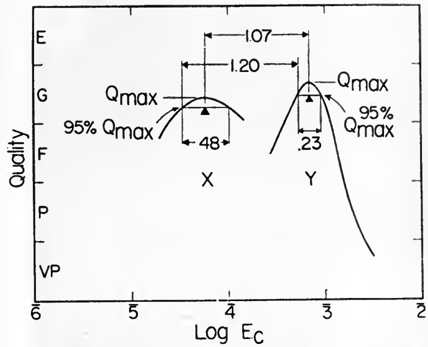

Fig. 2. Hypothetical curves showing methods of measuring latitudes, relative speeds and relative exposure indexes of two materials used to photograph the same scene. These values for this scene are respectively the antilogarithms of (a) the widths of the curves at 95% of the peak value, (b) the distance between the left ends of the horizontal lines at this level, and (c) the distance between the midpoints of these lines.

and log camera exposure for two materials, *X* and *Y*, when used to photograph the same scene. The scene characteristics which might affect the maximum quality, exposure latitude, and optimum exposure on each material have been taken into account by the judges in their quality ratings from which these curves were obtained. A direct comparison between the properties of the two materials revealed by these curves can therefore be made without further consideration of the scene characteristics. A number of similar sets of curves will provide increasingly useful information about the relative performance of the two materials.

An obvious conclusion which can be drawn from an inspection of the curves in Figs. 3 through 8 is that, since the curves are fairly smooth, quality varies uniformly with log camera exposure. This is something which might not be predicted from a casual inspection of the judgment data, since there were very large differences of opinion among the judges, both as to the quality of the reproduction of any given scene and the


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5230 A
5230 A

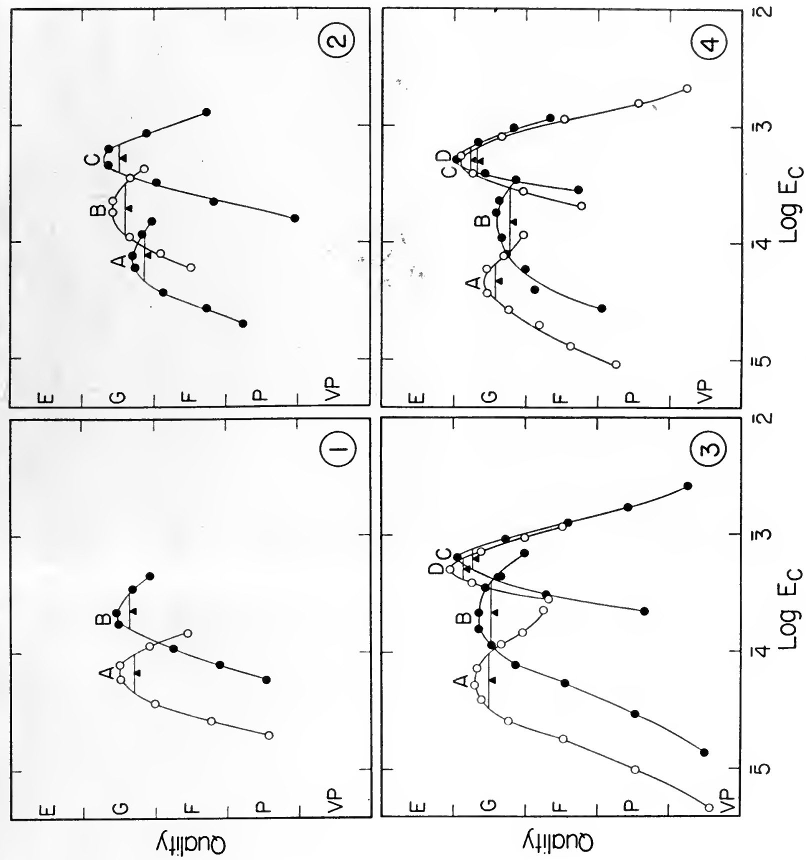
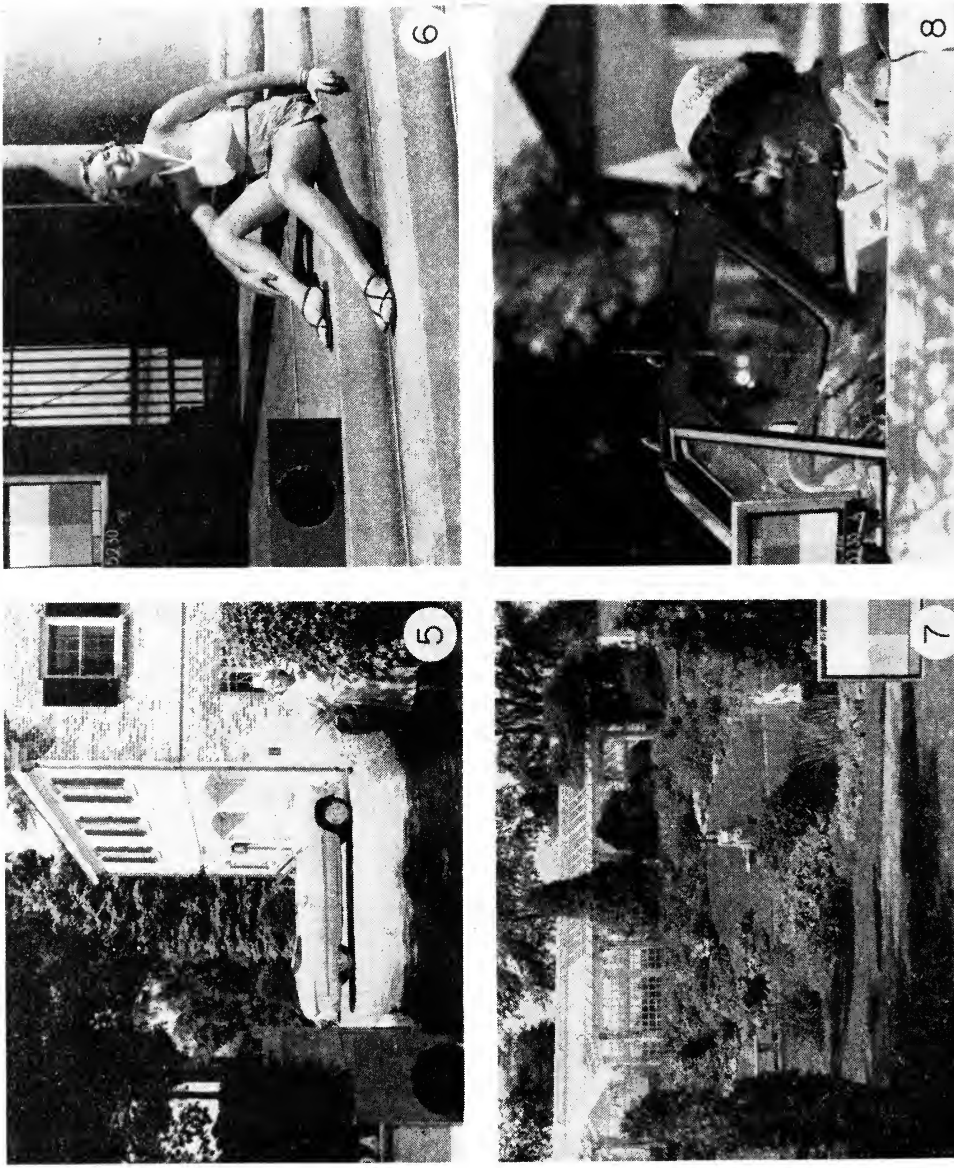


Fig. 3. Scenes 1–4 and respective curves of tone-reproduction quality as a function of the logarithm of camera exposure.

way in which the tone-reproduction quality changed with camera exposure. The smoothness of these curves also provides some assurance that there were no important errors introduced which raised or lowered the relative quality of a particular print from a negative at one camera exposure level. For example, if one of the prints in a series from a given scene had been either too light or too dark relative to the other prints in the series, the point representing this print on the quality curve might be expected to cause a deviation from a smooth curve. An inspection of the curves shows that such occurrences were very infrequent.

The first question which one might hope to answer by inspecting the curves presented here is, "What is the range of camera exposures which will yield negatives from which high-quality prints can be made?" To answer this question, the desired quality level must first be chosen. It will be noted that the peaks of a very few of the curves fall in the "excellent" region. Although many of the judges rated some of the prints from each scene as "excellent," disagreement among the judges as to which prints were "excellent," as well as the fact that some judges gave all the prints a lower rating, produced an overall rating of "good" for the prints in the vicinity of the peak of the curves in most cases. It is likely that the variations



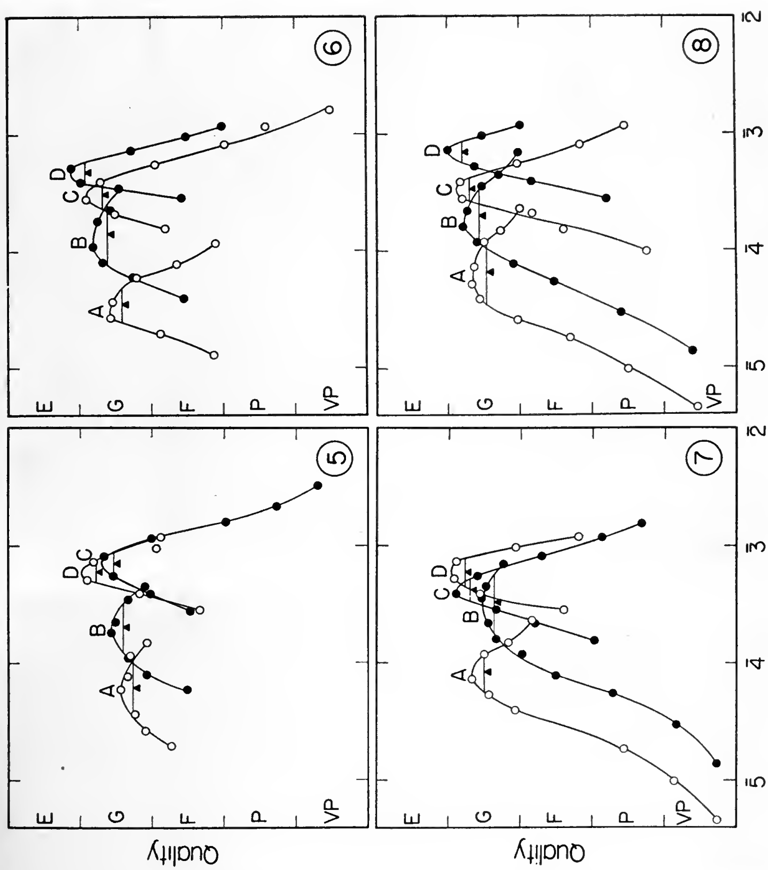
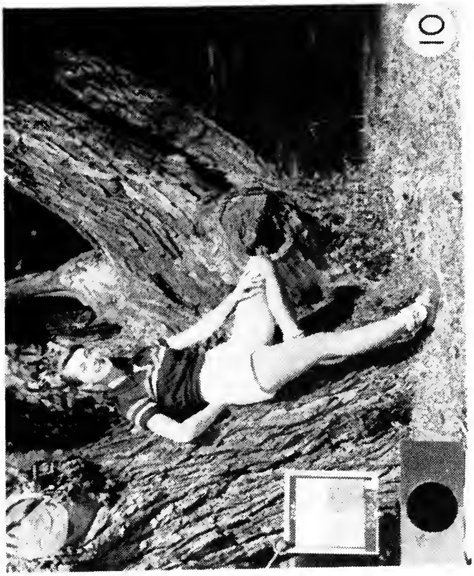


Fig. 4. Scenes 5–8 and respective curves of tone-reproduction quality as a function of the logarithm of camera exposure.

from scene to scene of the peak quality obtained with each material are partly the result of the observers being influenced more or less unconsciously by the nature of the scene itself. In other words, the best possible reproduction of a very pleasing scene may be rated higher, on the average, than the best possible reproduction of a scene which is less pleasing. However, it would be difficult, if not altogether incorrect, to attempt to estimate the extent to which this had occurred and make corrections for it by adjusting the curves upward or downward. The best way to avoid systematic errors which might originate in this way is to use a large number of scenes. For a given scene, the relative maximum qualities obtained with the various materials is, of course, a significant indication of the tone-reproduction characteristics of the materials, since any subjective influence which the scene itself might have exerted on the observers is canceled out in comparing curves for the same scene.

When curves such as these are available, for which the ordinates represent absolute levels of quality, there are at least two ways of determining the range of camera exposures over which "high-quality" prints can be obtained. The first is to locate the points on either side of the peak of each curve at a certain fixed quality level. The second is to locate the points on either side of the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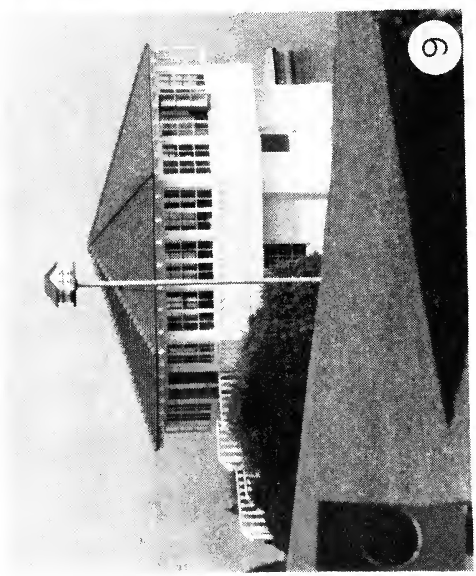
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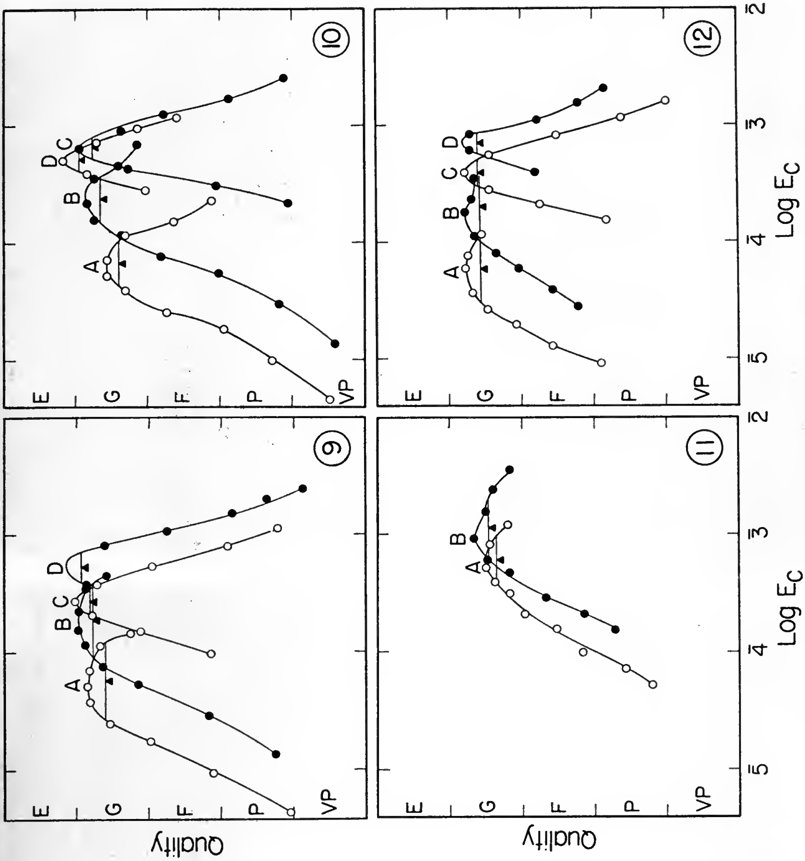

Fig. 5. Scenes 9–12 and respective curves of tone-reproduction quality as a function of the logarithm of camera exposure.

peak of each curve which fall at a given percentage of the maximum quality level for that curve. Of these alternatives, the second seems to be preferable for two reasons. If a high, fixed quality is used, it will be found that the peaks of the curves for some of the materials lie below this level, from which fact one might draw the incorrect conclusion that values of speed and exposure latitude cannot be determined for those materials. The second reason is that the potential maximum quality which can be obtained in any given case should not be ignored, as it would be if any fixed quality level were used, since, in fact, the attainment of this maximum quality is the desired objective for which any exposure recommendations which can be deduced from these curves will be used.

For the purpose of comparing the speeds of the four materials used in these tests, horizontal lines have been drawn at a level equal to 95% of the peak quality for each curve. The abscissas of the points at which these lines intersect each curve represent the smallest and largest values of log camera exposure which will yield this percentage of the maximum quality. The lengths of the lines between intersections represent the logarithms of the camera exposure latitudes. The camera exposure latitude is the ratio between the greatest and the least camera exposures which will produce the desired quality.

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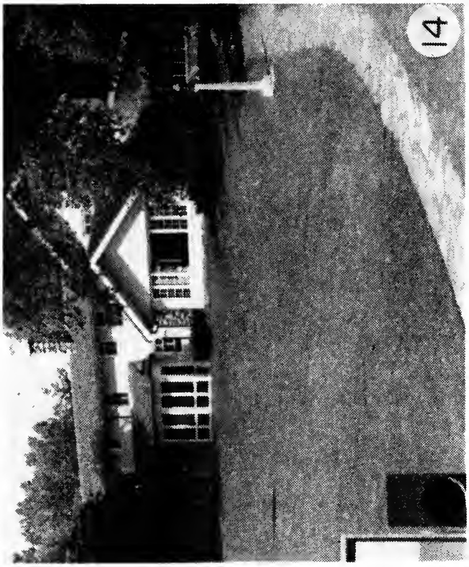

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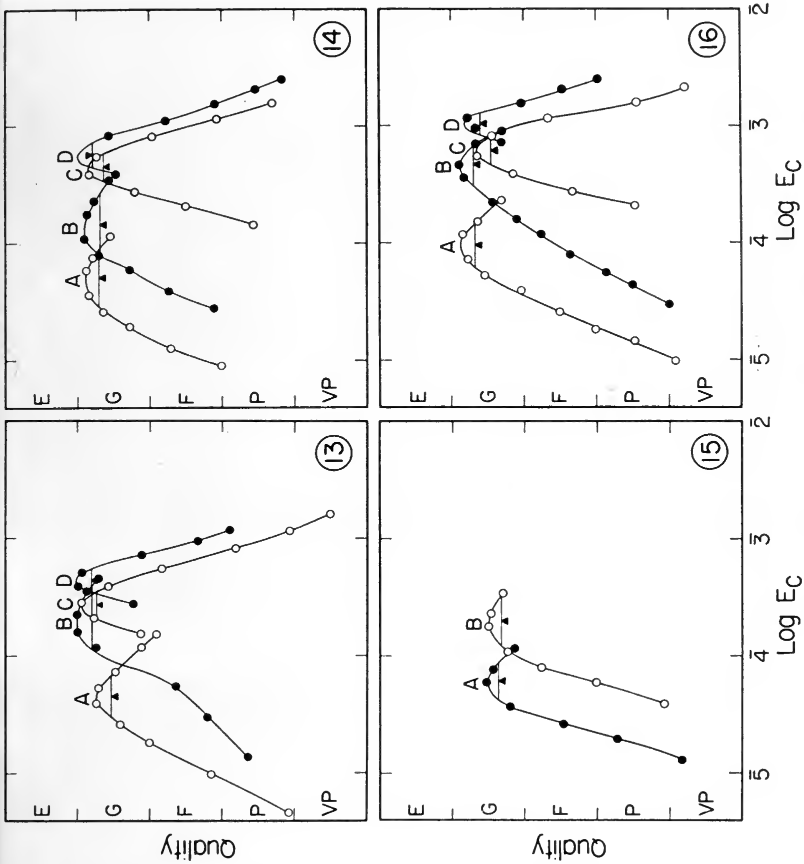


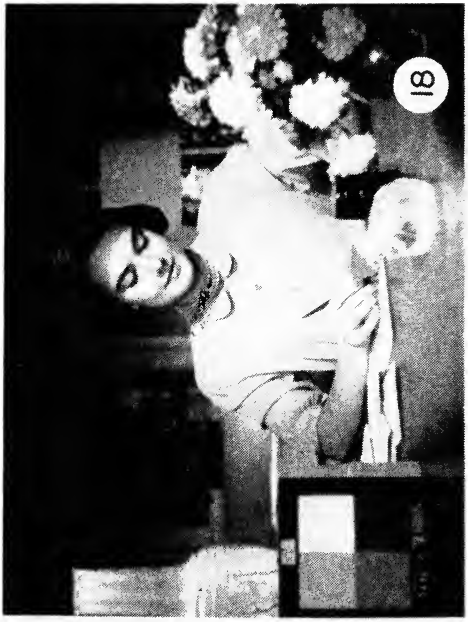
Fig. 6. Scenes 13–16 and respective curves of tone-reproduction quality as a function of the logarithm of camera exposure.

The logarithmic values measured from the curves for each scene are presented in Table I.

It has been stated earlier in this paper that the speed of a motion-picture negative film is inversely proportional to the minimum camera exposure required to produce a negative from which a positive print can be obtained that will give a projected screen image of high quality. For a given scene, then, the relative speeds of the materials are proportional to the camera exposures represented by the lefthand intersections of the horizontal lines at the 95% level with the respective curves. For any two materials the difference between the log E_c values for these points represents the logarithm of the ratios of the speeds of the two materials. The average ratio of the speeds of the materials can be determined from the average difference between the log camera exposures for these points for all the scenes studied. These differences are tabulated and the averages shown in Table II.

The curves of quality *vs.* log camera exposure presented here cannot be used to determine absolute speeds. A discussion of methods for deriving speed values is outside the scope of the present report.

The difference between *speed* and *exposure index* should be emphasized at this point. The speed of a photographic material is related to the *least* exposure which can be given to obtain a final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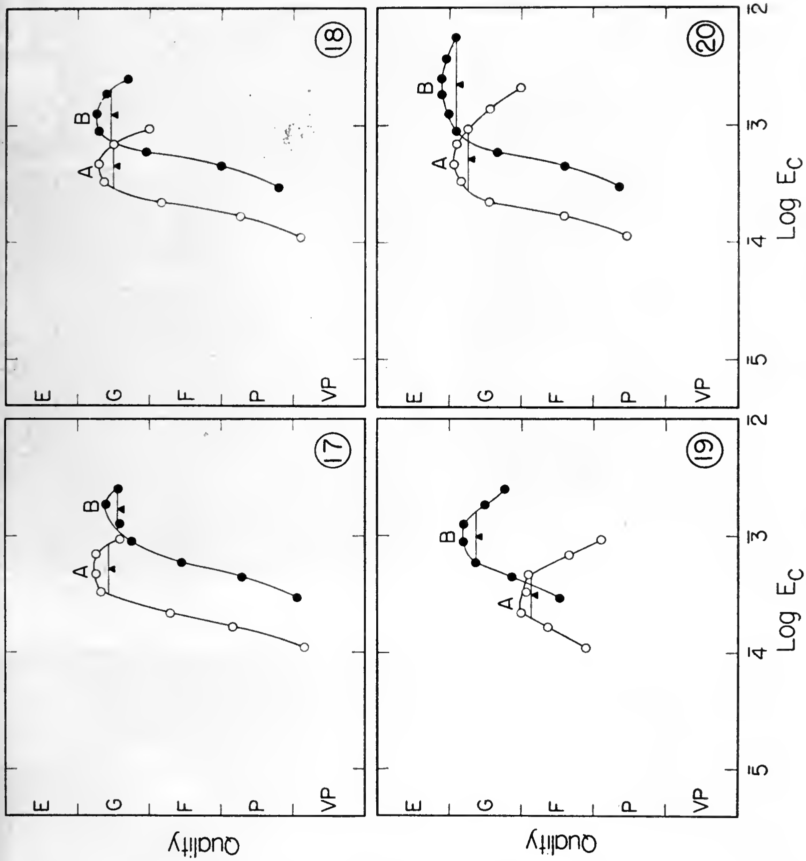
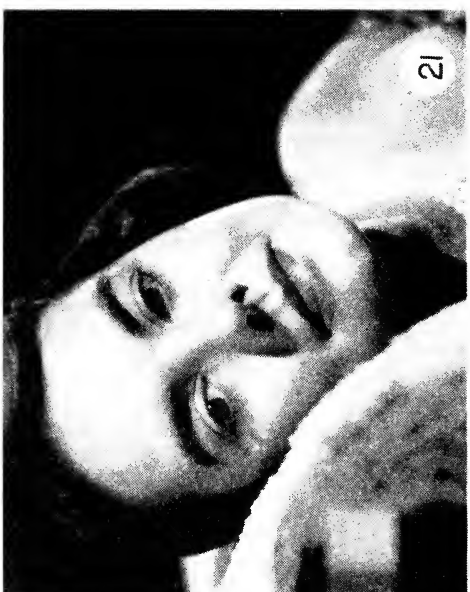


Fig. 7. Scenes 17–20 and respective curves of tone-reproduction quality as a function of the logarithm of camera exposure.

quality of a desired level. The exposure index, on the other hand, is related to the exposure which can safely be recommended in practice to produce final quality of the desired level. If an exposure index is used which results in the same camera exposure as that which is indicated on the curves of quality *vs.* log E_c by the speed point, then an error by the photographer in determining what camera exposure to use may result in his giving an exposure which is less than that required for a final result of high quality. The photographer using an exposure index in practice should find that he has a margin for error in the underexposure direction. The camera exposure latitudes which are tabulated in Table I show that there is a range of about $1\frac{2}{3}$ camera stops for Background-X Film, over which, on the average, at least 95% of the maximum attainable quality will be reached. For Plus-X Film, this range is, on the average, about $1\frac{1}{3}$ camera stops.

The exposure recommendations, i.e., the exposure index, which the photographer will use should be such that his results will, on the average, lie in the 95 to 100% maximum quality, Q_{max}, region. If it can safely be assumed that most of the photographers who use the exposure recommendations will be equipped to measure the illumination on their scenes and make necessary settings of shutters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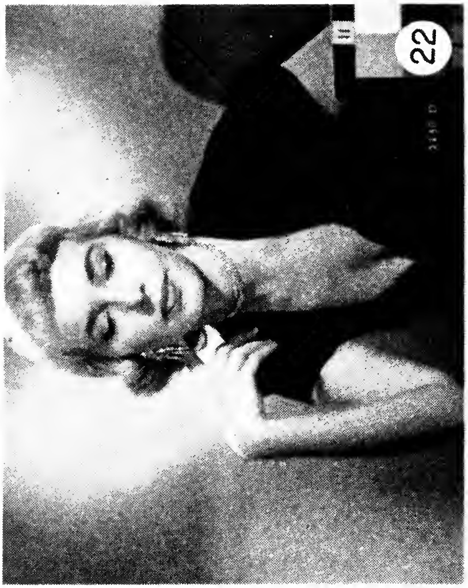
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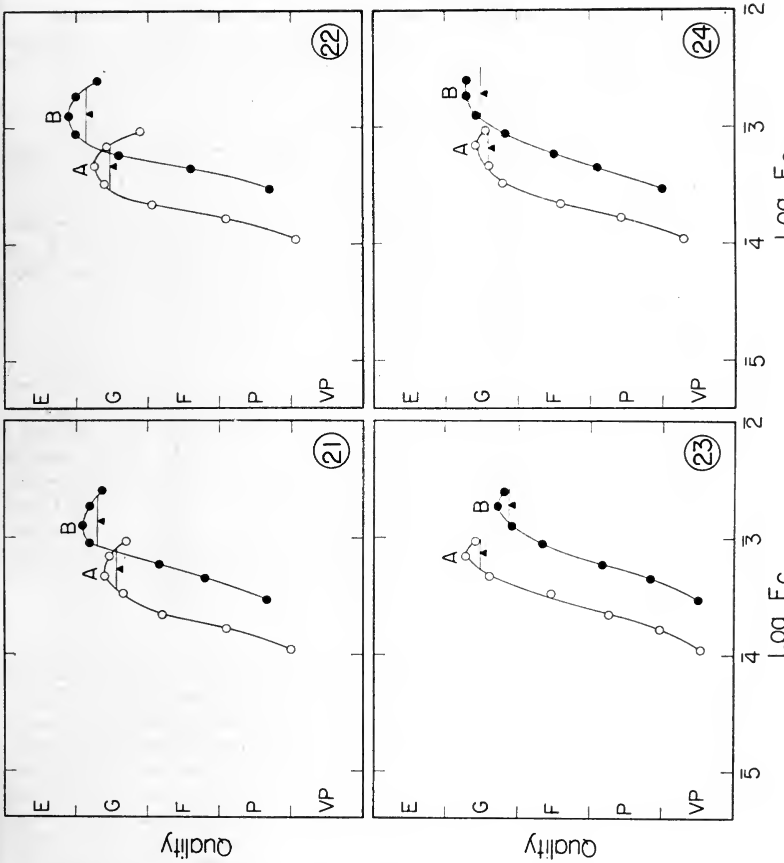

Fig. 8. Scenes 21–24 and respective curves of tone-reproduction quality as a function of the logarithm of camera exposure.

and lens apertures with a high degree of accuracy, then an exposure index can be assigned which is based on an exposure near the left end of the 95% Q_{max} line. The photographer can then use lenses of smaller aperture, shorter exposure times, or less light on his scene, all of which are factors that may be economically significant. In the present study, the midpoint of the 95% Q_{max} range has been selected as the point from which to determine relative exposure indexes. This has been done primarily for the purpose of illustration, and a final decision on this point will not be made until other studies are completed.

The differences between the logarithms of the camera exposures at the midpoints of the high-quality ranges are tabulated in Table III. The hypothetical curves for *X* and *Y* in Fig. 2 illustrate the fact that when the latitudes of materials being compared are different, the ratios between the speeds and the exposure indexes determined from the quality curves will, in general, be different.

Aside from the differences in latitude, there are no striking differences between the quality of the screen images which can be obtained from negatives on Background-X and those on Plus-X Film. There is some evidence that Background-X Film produces higher quality with scenes in which highlight and middletone details predominate or

Table I. Camera Exposure Latitude (Logarithmic).

Scene	Background-X	Plus-X
1	0.31	0.32
2	0.44	0.43
3	0.56	0.48
4	0.60	0.29
5	0.42	0.49
6	0.52	0.30
7	0.51	0.33
8	0.47	0.56
9	0.62	0.66
10	0.39	0.38
11	0.52	0.41
12	0.56	0.57
13	0.54	0.36
14	0.52	0.49
15	0.43	0.33
16	0.35	0.38
17	0.32	0.44
18	0.43	0.39
19	0.45	0.39
20	0.80	0.55
21	0.46	0.36
22	0.42	0.32
23	0.32	0.29
24	0.47	0.40
Average	0.48	0.41

represent important centers of interest in the scene. Plus-X Film seems to produce somewhat higher quality when there are large important shadow areas in the scene. The quality differences for individual scenes are small in most cases.

Summary

This investigation has shown that psychophysical techniques which relate subjective attributes to physical variables can be used to determine the variation in the quality of projected positive screen images from negatives which have received varying amounts of exposure. The results which have been obtained can be made the basis for a sensitometric speed and exposure index criterion for motion-picture negative films.

Acknowledgments

The author wishes to acknowledge many helpful suggestions from C. N. Nelson. F. T. Percy and his associates, William Cannan and Earl Kage, were responsible for the arrangement, lighting and photography of the scenes.

References

1. L. A. Jones, "Psychophysics and photography," *J. Opt. Soc. Am., 34:* 66–88, Feb. 1944.

2. L. A. Jones and H. R. Condit, "Sunlight and skylight as determinants of camera exposure," *J. Opt. Soc. Am., 38:* 132, Feb. 1948.

Discussion

Peter Krause (Ansco): Would you care to explain for us why an excellent quality rating was not given on any of the curves?

Mr. Sorem: Many of the judges placed the peaks of their individual curves high in the excellent region. At the same time, some of the judges were more critical, and they never gave any of the exposures an excellent rating. Also, although it may be surprising after seeing these curves, there was quite a lot of disagreement among the judges as to where the maximum quality points lay. Some judges like the highlights to be full of detail. Others like the shadows to be very excellently reproduced, and consequently the peaks of their individual curves were shifted one way or the other, and as a result when the values from the individual curves were averaged, the excellent judgments were pulled down considerably.

Mr. Krause: Would that not mean that perhaps the basis you have selected now for determining camera exposures is a little dangerous, because consumers might vary?

Mr. Sorem: That is one reason why we used more than thirty observers. We knew that thirty is about the minimum number which you can use safely to get an unbiased average from the group.

Mr. Krause: It has been my experience that people who judge their own pictures are much more critical and will judge them quite differently from people judging photographs with which they have no personal connection. In this particular instance, they were disinterested observers, were they not?

Mr. Sorem: That is correct.

Mr. Krause: Do you feel that there is a

Table II. Differences Between Logarithms of the Minimum Camera Exposures Producing High Quality.

Scene	Ektachrome Kodachrome	Kodachrome Background-X	Background-X Plus-X Outdoor scenes	Background-X Plus-X Indoor scenes
1	..	..	0.55	
2	..	0.55	0.39	
3	−0.09	0.66	0.53	
4	+0.03	0.71	0.35	
5	−0.05	0.65	0.54	
6	+0.21	0.48	0.49	
7	0.12	0.27	0.50	
8	0.33	0.37	0.52	
9	0.27	0.36	0.54	
10	−0.11	0.53	0.53	
11	..	..	0.20	
12	+0.29	0.46	0.52	
13	0.23	0.27	0.58	
14	0.11	0.64	0.44	
15	..	..	0.46	
16	0.26	0.19	0.69	
17				0.54
18				0.40
19				0.47
20				0.51
21				0.37
22				0.40
23				0.39
24				0.44
Average	0.13	0.47	0.49	0.44

Note: The differences in each column represent the minimum camera exposure producing 95% of the maximum quality for the first named material minus the minimum camera exposure producing 95% of the maximum quality for the second material.

difference between the judgment of an interested and disinterested person?

Mr. Sorem: I haven't considered the matter on that basis. I feel that one might expect a difference between the opinion of an expert and a nonexpert. However, we have found over a series of experiments that if you average the opinions of the experts and the nonexperts separately, and if each group is large enough, that the averages tend to be the same.

Mr. Krause: The curves seem to decrease on both sides of the correct exposure at about the same rate, so that if you were to include a safety factor against underexposure, would you not then run the risk that overexposure would also occur and would give a similar decreasing quality?

Mr. Sorem: Yes. That consideration, of course, points to the desirability of putting the recommended exposure at the midpoint.

Gordon A. Chambers (*Eastman Kodak Co.*): I'd like to comment on the first question. I happen to be one of those asked to be a judge. It must be kept in mind that the exposures covered were very wide in range, so that the first scene a judge saw was really pretty bad. As a judge you started in the dark — put a mark way down near the bottom of the chart for scene A; and then obviously as it began to get better, you started going up the scale, and you kept thinking, I've not yet reached the best possible print. As you were working up the page, and were finding prints in the good range, pretty soon they started getting worse. If you had been able to do it all over again you might have moved the whole curve up on the page. But I think that the number of people who had been accustomed to judging motion pictures were inclined to be on the conservative side when they

Table III. **Differences Between the Logarithms of the Camera Exposures at the Midpoints of the High-Quality Ranges.**

Scene	Ektachrome Kodachrome	Kodachrome Background-X	Background-X Plus-X Outdoor scenes	Background-X Plus-X Indoor scenes
1	..	..	0.54	
2	..	0.43	0.40	
3	−0.10	0.46	0.58	
4	+0.04	0.52	0.50	
5	−0.04	0.55	0.51	
6	+0.19	0.34	0.61	
7	0.16	0.11	0.59	
8	0.33	0.23	0.48	
9	0.29	0.16	0.51	
10	−0.10	0.44	0.55	
11	..	..	0.27	
12	+0.27	0.29	0.53	
13	0.21	0.10	0.68	
14	0.11	0.49	0.45	
15	..	..	0.51	
16	0.23	0.12	0.68	
17				0.51
18				0.44
19				0.50
20				0.64
21				0.41
22				0.46
23				0.47
24				0.48
Average	0.13	0.33	0.52	0.48

Note: The differences in each column represent the logarithm of the designated exposure for the first named material minus that for the second.

did this judging. They kept thinking, "the daisies in the next field are going to be better." So I think that the fact that the curves on the whole don't land up in the excellent range is a matter of human failing.

Mr. Sorem: I mentioned that the observers were given a preview of each series before being asked to record their judgments. We believe that allowing them to see the pictures twice minimized the effect described by Mr. Chambers. It is evident from the curves, that we did go about $1\frac{1}{2}$ stops in the overexposure direction from what is ordinarily considered normal and $1\frac{1}{2}$ stops in the underexposure direction. It was sometimes easier to go to underexposure than to overexposure. Also, in some cases, it was not possible to go that far in the overexposure direction, particularly for the indoor scenes, where there was the problem of getting sufficient light.

W. R. Holm (Du Pont Photo Products Dept.): You said that you were going to relate the exposures with the exposure meter readings, and I think this would be very interesting. Did you use a Macbeth Illuminometer both indoors and outdoors?

Mr. Sorem: We did.

Mr. Holm: Did you filter it outdoors, or did you use tungsten light?

Mr. Sorem: We used a filter.

Mr. Holm: Since this is a visual instrument, did you notice any differences between it and the others of the group?

Mr. Sorem: We have not proceeded far enough in our analysis of the exposure meter readings to determine that. I imagine we may find some differences.

Mr. Holm: What kind of filtering did you use with the Macbeth Illuminometer?

Mr. Sorem: We used a filter for the daylight scenes which produced a color match between the images of neutral areas in the scene and the comparison field in the instrument.

New 35mm Television Film Scanner

By E. H. TRAUB

New solutions for the film transmission problem for both black-and-white and color are described, comprising (1) nonstorage flying-spot scanning technique, (2) continuous exposure and (3) continuous film motion combined with optical compensation. A new form of optical compensator is then discussed which is both simple and small and which provides the possibility of solutions for film-shrinkage correction and iso-film-transport. The new optical compensator is corrected for various aberrations and has good optical efficiency. A color television film scanner incorporating these features is described.

Over three years ago the Philco Research Division started a program of development leading toward the construction of a film scanner, to provide a source of color television signals. Originally planned as a research aid in the development of color television systems and color home receivers, the new Philco Television Film Scanner provides unequalled quality of reproduction from both black-and-white and color motion-picture film.

Background

At the very outset of this development program, it was recognized that existing black-and-white film transmission techniques were far from satisfactory in quality, and that the adaptation of these existing techniques to color television would result in still further deterioration of picture quality combined with unwarranted and excessive complexity of the apparatus.

The type of apparatus generally in use at present comprises a film projector converted to 3:2 ratio intermittent operation used in conjunction with means for providing pulse-exposure of light projected onto a storage scanning tube. The unsatisfactory film reproduction in black-and-white resulting from this combination has long plagued equipment manufacturers, broadcasters and the television audience. For color television operation along these lines, three storage scanning tubes instead of one would have to be used, requiring mutually precise registration, both electronically and optically. The attendant complexities arising from this triplication require no emphasis.

The Problem

Evaluation of these factors led to the conclusion that existing techniques must be regarded as obsolete. A completely fresh approach to the film transmission problem would have to be made which, in terms of picture quality, would give results equal or superior to those of a studio camera and which would be capable of excellent color performance without adding undue complexities to the apparatus.

It was decided that the existing concepts, involving (1) storage scanning

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tube, as typified by the iconoscope, (2) pulse-exposure and (3) intermittent film motion, would have to be abandoned entirely and replaced by the new, diametrically opposite concepts of (1) nonstorage (flying-spot) scanning tube, (2) continuous exposure and (3) continuous film motion combined with optical compensation.

This in turn would mean that the direction of the light-path would be completely reversed. The important implication of this change is that triplication of the scanning tube would become quite unnecessary for color operation. This would entirely avoid the triple registration problem previously referred to and would represent a tremendous simplification.

Such a system would provide the ideal in television film reproduction.

The Solution

In attempting to translate these fresh concepts into practice, Philco was in the fortunate position of being able to draw on a rich experience in nonstorage (flying-spot) scanning techniques, as exemplified by its "Flying-Spot Scanner" for opaque and transparent slides, already in use in numerous laboratories and television stations.

The practical realization of the remaining two features of the "ideal" system, namely continuous exposure and continuous film motion, were dependent on discovering a suitable optical compensator. This, then, proves to be the key to the whole system.

Much time, effort, and money had been spent over the past fifty years by organizations, both here and abroad, to develop such a device but without much practical success. Previous optical compensators were all too inefficient, too complicated or optically imperfect in operation.

It is actually not too obvious that the same optical compensating device which is required for the projection of continuously moving film onto a screen is precisely the same device which is required in order to project a television raster from a flying-spot scanning tube onto a continuously moving film. The following explanation may help to clarify these two relationships.

In the first mentioned case the function of the optical compensator is to *immobilize* the film on the screen, whereas in the second case the function of the same optical compensator is to *chase* the film with an image of the raster. Thus we find in comparing projection of continuously moving film with flying-spot scanning of continuously moving film that the same optical system is used in both cases, except that the *directions* of the light-paths are reversed and the concept of immobilization is also reversed and becomes "chasing."

Technical literature abounds with hundreds of schemes for optical compensation, most of which, incidentally, do not work. Generally speaking, optical compensators fall under three general headings: (1) rotating and/or oscillating mirror devices; (2) rotating lens devices; and (3) rotating prism devices.

Mirror Methods. The classical example of a mirror type of optical compensator is represented by the Mechau projector which was designed and built in Germany in the 1920's. It is important because it was the first technically successful continuous projector the world had ever seen. In spite of their relatively large size and complexity many hundreds of these projectors were built and sold, and until very recently their performance was not surpassed by any other similar device. Those of us who are working today in the field of optical compensation in relation to television cannot but have the greatest respect for the genius of Emil Mechau who is now revealed to us as being one of those rare men who in his technical conceptions was literally decades ahead of his time. Great credit must also go to F. Schröter who in the mid-30's for the first time defined clearly in a theoretical paper the interrelationship between the continuous film projector (proper) and the television film scanner using optical compensation.

Lens Methods. Generally speaking, lens methods of compensation have been less successful than mirror or other methods for a variety of reasons. The optical aperture of such systems is usually somewhat limited by aberration considerations and the problem of identity of a large number of lens elements is and remains a serious one. Moreover, there are the problems of precision adjustment of the lenses and of cost.

Prism Methods. These are generally polygonal derivatives of the plane-parallel glass-plate type of optical compensator. They are based on the physical-optical phenomenon that a ray passing through a parallel plate of finite thickness will be displaced proportionally to the angular rotation of such a parallel plate, at least for a reasonable number of degrees of rotation, beyond which, however, the law of operation may be said to break down and the displacement becomes nonlinear. The well known optical designer H. Dennis Taylor, who will be remembered for his invention of the now famous triplet lens, was the first to publish a theoretical analysis of this type of compensator. The prismatic-polygon type of compensator has a number of features which make it highly attractive: It is simple, consisting essentially of a one-piece optical component whose precision can be "*built in*" once and for all. There are no adjustments either during assembly or during operation. Moreover, the device is both small and light, and can be manufactured at very reasonable cost. Until very recently, however, the theory of operation, and in particular the theory of prismatic aberrations, was not too fully understood, nor were the results obtained with these devices too encouraging. In the past few years, however, improvements of a very substantial nature have been made in the field of prismatic polygons, these improvements being based on a much better insight into the theory of operation and on a number of new inventions. It is the purpose of this paper to describe a new Television Film Scanner which uses such an improved prismatic-polygon type of optical compensator.

Description of Optical Compensator*

Space does not permit a detailed technical description of the reasons underlying the various improvements and changes that have been made to the prismatic-polygon system, but the following description will serve to convey the nature of the device as incorporated in the 35mm television film scanner presently in production.

The rotating element is shown in Fig. 1. Several distinguishing features are readily apparent. The polygon is 24-sided, rotating once per second. It has a diameter of about 5½ in. The polygon is no longer a solid one, but has a large cylindrically polished hole cut in it. The polygon may be said to have sprocket teeth on it, or more correctly speaking the polygon is now so dimensioned that it can be fitted within the confines of a film sprocket. This permits the film to be partially wrapped around the polygon in such a manner that each film frame is optically and mechanically registered with each corresponding facet of the polygon. This is a most important feature of great practical significance. It is referred to as isotransport. In the absence of isotransport, when film velocity and polygon velocity are separately established, four dynamic conditions must be ful-

* An invention of Dr. John C. Kudar. Philco has the exclusive license under Dr. Kudar's applicable patents and applications, but only for the television field.

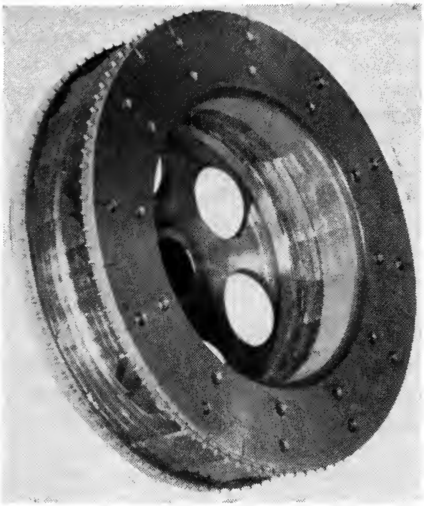

Fig. 1. 24-sided polygon and sprocket assembly.

filled in order to obtain compensation of film motion. These are:

(1) Uniform film velocity.
(2) Uniform polygon velocity.
(3) Synchronism between (1) and (2).
(4) Phase identity between (1) and (2).

Isotransport enables all four conditions to be fulfilled simultaneously and automatically, and in fact neither uniform film velocity nor uniform polygon velocity is any longer essential as long as both film and polygon rotate at the same speed.

Contained within the rotating polygon is a stationary optical system called a "core." This is shown in Fig. 2. It consists of a stationary platform which carries a number of optical elements essential to the functioning of the system. These elements are first, two plano-convex cylindrical lenses

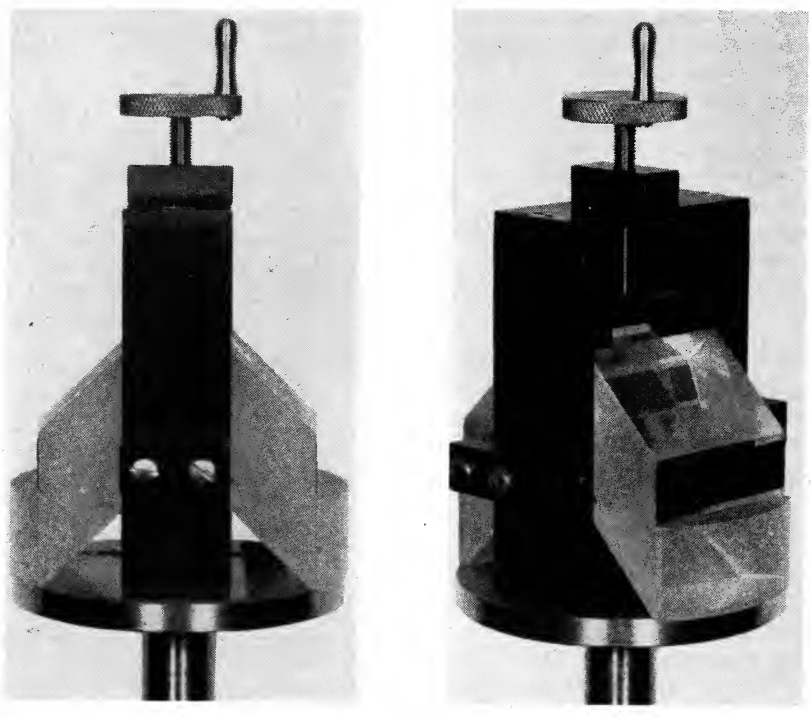

Fig. 2. "Core" assembly and shrinkage compensator.

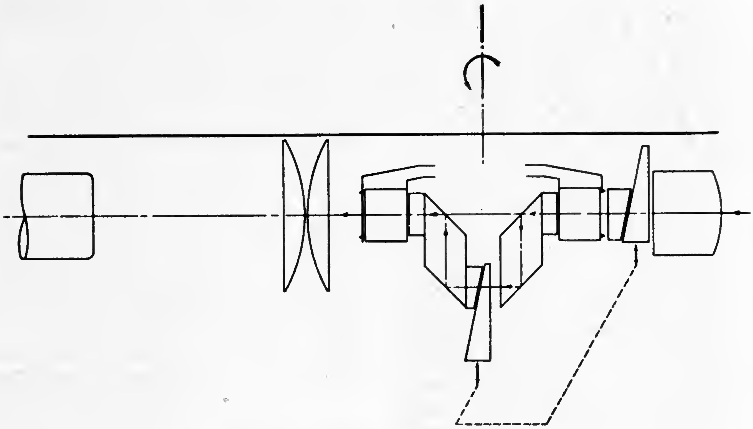

Fig. 3. 35mm optical system.

whose function is to form a zero-focus air gap between the rotating polygon and the other optical components which constitute the core. Second, there are two prismatic rhombs whose function is primarily to serve as path-length extenders in the optical sense. Without such path-length extension the diameter of the polygon could not be reduced sufficiently to enable it to be contained within the diameter of a film sprocket. Third, the core contains an adjustable optical shrinkage compensator the nature of which will be described later. Certain of the optical elements of the core are made of glass having a different dispersion from that of the polygon, which serves the further useful purpose of enabling the designer to correct the polygon for lateral chromatic aberration as a function of angular rotation. Other prismatic abberations, incidentally, can be readily controlled in design in a composite prismatic polygon of this type and can be kept within highly acceptable limits. Certain others, such as the spherical and longitudinal chromatic aberrations, can be corrected by means of a projection lens specifically designed to operate through the requisite glass path length.

A sectional view of the entire optical system is shown in Figure 3. The path-length extension created by the rhombic prisms is readily recognizable. The nature of the shrinkage compensator is also revealed.

It is an inherent feature of all machines using continuously moving film that their operation depends on the degree of shrinkage of the film. Therefore, in all such machines provision for shrinkage compensation of some kind must be made. In a prismatic-polygon type of optical compensator the best way to compensate for film shrinkage is effectively to vary the optical diameter of the polygon. This is, of course, quite impracticable in the case of the classical solid polygon, but is quite possible with the type of compensator here described. It is accomplished by introducing the optical equivalent of a parallel plate of variable thickness into the optical path between opposite pairs of facets of the polygon. The physical embodiment of this parallel plate of variable thickness is achieved by the subterfuge of sliding a thin wedge against a stationary wedge having a similar slope angle. The in-and-out movement of this wedge against its corresponding mate, separated by a very small air gap, then varies the optically effective path length

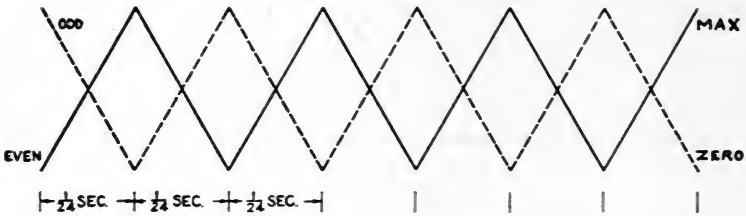

Fig. 4. Lap dissolve.

through the polygon and thus compensates for film shrinkage.

Optical film-shrinkage compensation of this type in turn introduces another complication which must not be overlooked, namely that varying the relative amounts of glass and air in the optical path between the projection lens and the film will in turn cause considerable defocusing of the image. Refocusing could of course, be accomplished by readjusting the projection lens, but this in turn would produce a slight change in magnification of the optical system. In order to avoid these difficulties, a second plane-parallel plate of variable thickness is introduced into the optical system between the projection lens and the polygon. This again consists of a stationary and moving wedge operating as an entity. This is called the "refocus compensator." The sum of the thicknesses of the shrinkage compensator and refocus compensator is kept constant by means of push-pull operation of the shrinkage-compensating wedge and refocus-compensating wedge respectively. This manner of operation then results in a shrinkage-compensating device of constant focus and constant image size irrespective of setting. In practice, the two wedges are ganged together and operated from a common control.

Methods of Picture Transition

In film devices of all kinds which use continuously moving film in conjunction with optical compensation, some specific method of picture transition from one film frame to the next must be used in the place of the intermittent pull-down which is employed in a conventional projector. Numerous methods of picture transition are possible. The method used in television film scanner described here is that called "lap dissolve" which can best be described as the alternate fading in and fading out of successive film frames. The light intensity from the odd- and even-numbered film frames is illustrated in Fig. 4, as this varies with time. For instance, while an odd-numbered film frame is fading from maximum to minimum light intensity on the screen, the successive even-numbered film frame is fading in from zero to maximum intensity. The important thing from the point of view of truly continuous and flicker-free operation is that the sum of the two light intensities should always add up to unity. Thus it will be seen that in lap dissolve, two successive film frames are always superimposed on the screen, except at one infinitely small moment when one film frame alone appears on the screen because the preceding frame has faded down to zero intensity and the succeeding frame has not yet had a chance to rise to a finite level of intensity.

The dynamic manner of operation is shown in Fig. 5 which relates the position of rotation of the polygon to the lap-dissolve diagram. The first view shows the polygon in the "normal" position, namely that which would be used if it were desired to transmit merely one stationary film frame (T_0). The second view shows the polygon in a position of rotation one-half frame-time later ($T_0 +$ 1/48 sec). At this moment the light from the raster is seen to be evenly divided between two successive film frames. The third view shows the polygon a small instant later yet (T_0 + 1/24 sec + δ). This moment in time in the rotation of the polygon is a particularly interesting one, as it clearly demonstrates that when precisely one facet is illuminated by the projection lens the chasing action of the optical compensator causes the raster to move potentially over a height of three film frames in extent; in other words, a "gate" three film frames high is required even though no more than two film frames are utilized simultaneously at any one moment.

The heart of the television film scanner, which is the optically compensated "picture head" or film-traction mechanism proper, is shown in Fig. 6. The ganged shrinkage control knob is easily recognizable as well as the polygon surrounding the stationary-core assembly and the refocus-compensator device. The mechanical simplicity of the picture head requires no emphasis, except to point out that the main large picture sprocket is not motor driven, but is driven by the film. Figure 6 also shows the relationship between picture head and the tri-color photocell housing. The special 4-in. flying-spot scanning tube is shown in Fig. 7. Its face is almost completely filled by a raster $2\frac{1}{2} \times 3$ in. in size which is of course a perfectly conventional 525-line, 60-field interlaced raster whose vertical and horizontal return traces are completely suppressed for the establishment of black level. The tube has a special fine-grain, short-persistence phosphor developed by the Lansdale Tube Company. It is operated at about 30 kv and at a beam current of 250 μa. The complete equipment is shown in Fig. 8.

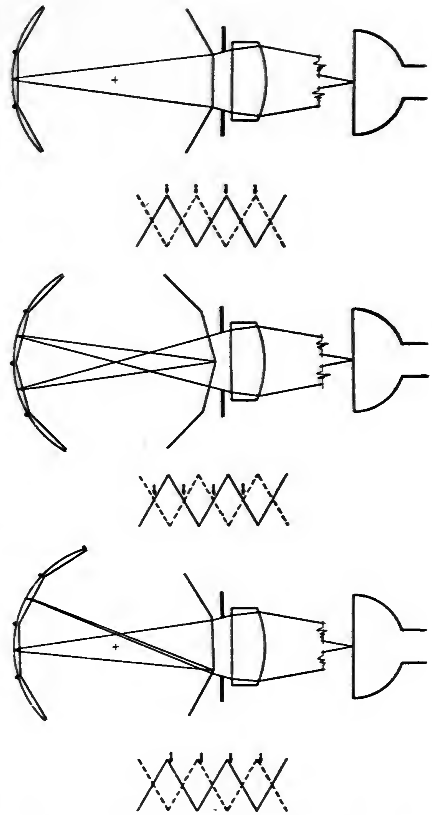

Fig. 5. Operational Diagrams: Position 1 (top); Position 2 (center); Position 3 (bottom).

Summary

The special features of the 35mm television film scanner may be summarized as follows:

(1) Continuous film motion, which has the advantage of greatly reducing film wear, implies a simpler and more reliable film-traction mechanism than is possible when operation is of the intermittent type.

(2) The optical compensator, which is a specially corrected type of rotating prismatic polygon, is a relatively small component revolving at a very low speed. This device has its own precision permanently "built into" it. Once manufactured it cannot change or distort in any manner, thus never requires further adjustment or maintenance.

(3) A film shrinkage correction device is provided as an integral part of

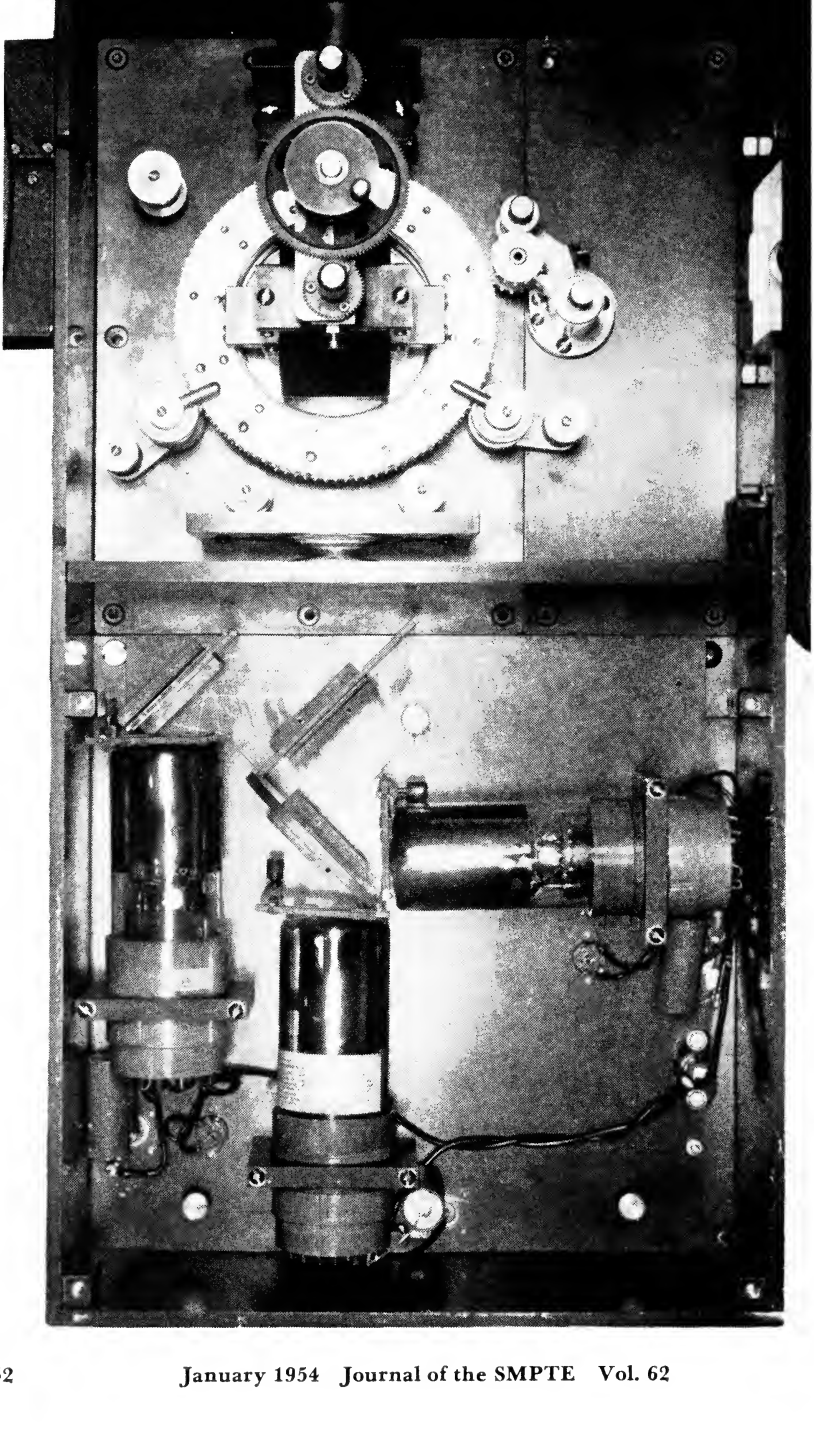

Fig. 6. Picture head mechanism and photocell housing

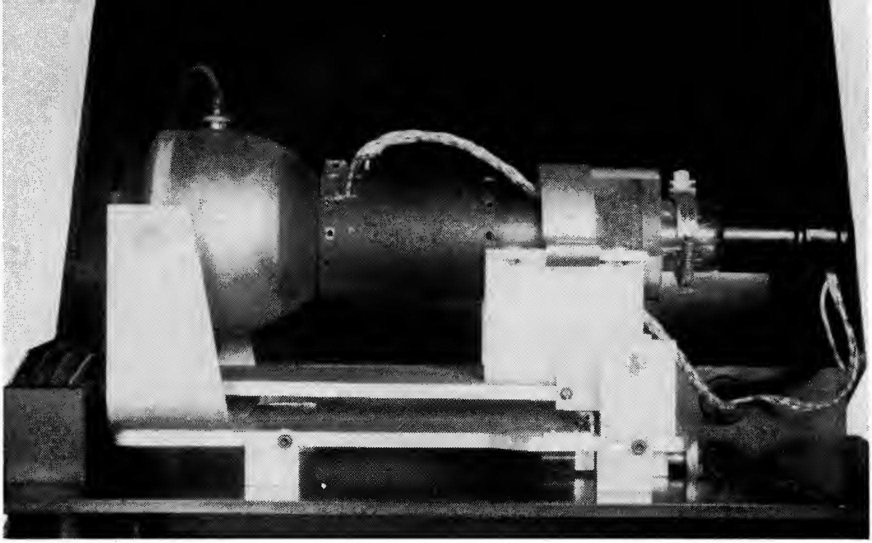

Fig. 7. Flying-spot scanner tube, with housing raised.

the optical compensator. This is preset at the beginning of a reel of film and thereafter requires no further attention.

(4) The exclusive isotransport feature is an inherent part of the television film scanner. This guarantees completely automatic registration between film motion and the optical compensator, always insuring their correct synchronism and phase relationship, regardless of film speed. It also avoids the necessity for vertical framing and provides pictures of extreme steadiness with freedom from flicker.

(5) Flying spot scanning is in itself a guarantee of the finest possible picture quality known to science today. It provides pictures of the finest resolution, superb half-tone reproduction, and a full range of contrast. The background level is automatically and accurately transmitted, and the picture is completely free from shading errors of any kind.

(6) This television film scanner is a *cold* scanner. The film cooling and burning problem does not exist, because of the complete absence of heat from projection lamps or arcs. The light on the film from the flying-spot scanning tube is absolutely cold.

(7) This television film scanner is a *universal* scanner.

(a) The scanner was designed from the outset for color operation but inherently also provides black-and-white pictures of excellent quality and complete freedom from noise. It gives color signals which can then be electronically repackaged to suit any of the several color television systems—simultaneous color, field-sequential color, line-sequential color or National Television System Committee compatible color system.

(b) The scanner operates at any film speed from zero upwards. Because of its cold operation, it is also possible to transmit stationary film frames, if desired.

(c) The scanner can simply and easily be converted to any existing foreign or domestic television standard, regardless of the number of lines or frames per second.

(d) The scanner is completely non-

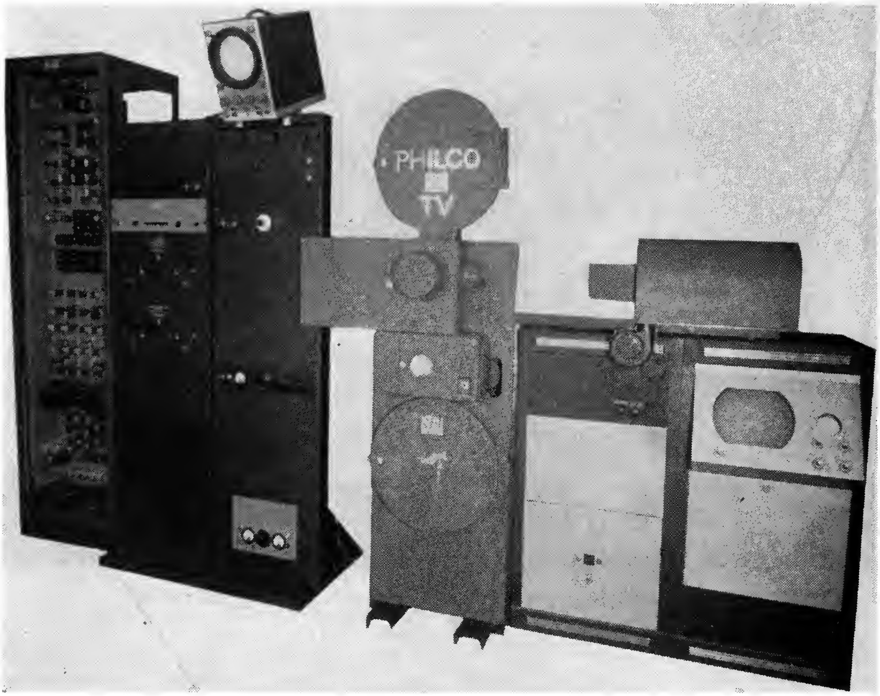

Fig. 8. Complete 35mm unit.

synchronous in operation, and with suitable power supplies can be used on any power-line frequencies. The nonsynchronous feature is, of course of particular importance in connection with the NTSC color system. The rigid relationship required in present monochrome film transmission, namely the necessity for a line-driven synchronous motor for projector drive to achieve synchronism of film transport with deflection, has been removed. In compatible color television, where deflection frequencies are obtained by division from a crystal control master oscillator operating at the color-carrier frequency, the tremendous advantage of the nonsynchronous method of operation of the television film scanner is obvious.

(8) Operational advantages of special interest:

(a) Short run-up time: this is practically instantaneous.

(b) The scanner can also be used as a caption or title scanner. It can, moreover, be readily multiplexed with a second picture head and, if desired, with a slide-transparency unit. It is here that the use of a stationary scanning raster is of special importance, as previewing between two picture heads or between film and slides becomes readily feasible.

(c) It offers the possibility of perfect timing of start of film programs or film inserts in live programs, by remote control if desired.

The film scanner here described is the 35 mm scanner now in production for several networks and research laboratories. A 16mm version is currently in an advance stage of development but it should be emphasized that it will differ in many technical details from the 35mm version, while preserving the essential features and advantages.

Fast-Cycling Intermittent for 16mm Film

By WARREN R. ISOM

A 16mm mechanism designed to advance the film during the vertical blanking time of the television system and its use with a flying-spot film scanner for color television is described. The order of the forces encountered is indicated. Also, solutions to certain auxiliary problems are given as well as operating characteristics and performance data.

For a long time, the need has been recognized for a film-handling machine that is capable of transporting the film from frame to frame within the vertical blanking time of the television system. Of the uses for such a machine, none is more important than that related to the problems of color television. The purpose of this paper is to describe a 16mm mechanism that advances the film in the vertical blanking time and to tell something of its use with a flying-spot scanner as a source of a video signal for color television.

Use in the System

The scanner is a flying-spot tube, RCA No. 73236-D, the raster of which is imaged by a $f/1.6$ objective lens upon the frame of film in the gate of the film transport (Fig. 1). This frame of film is held in the gate alternately for two and three scans, being advanced during the vertical blanking time. The light that is transmitted through the film is modulated by the photographic image upon the film. This modulated light is gathered up and directed by suitable condensers through selective reflecting and transmitting dichroics to the sensitive surfaces of electron multipliers, the red component to an RCA 6217 tube, the blue and the green each to an RCA 5819 tube. There is a preamplifier for each of these tubes, which work into channel amplifiers and other associated gear for the final processing of the original video signal to NTSC proposed standards. The preamplifiers as well as the servicing equipment for the flying-spot itself are a part, physically, of the film scanner unit. However, the scope of this paper does not include any further mention of this equipment. The principal concern here is the intermittent mechanism, shown in Figs. 2 and 3.

Presented on October 7, 1953, at the Society's Convention at New York by Warren R. Isom, Radio Corporation of America, RCA Victor Div., Engineering Products Dept., Camden, N.J.
(This paper was received October 9, 1953.)

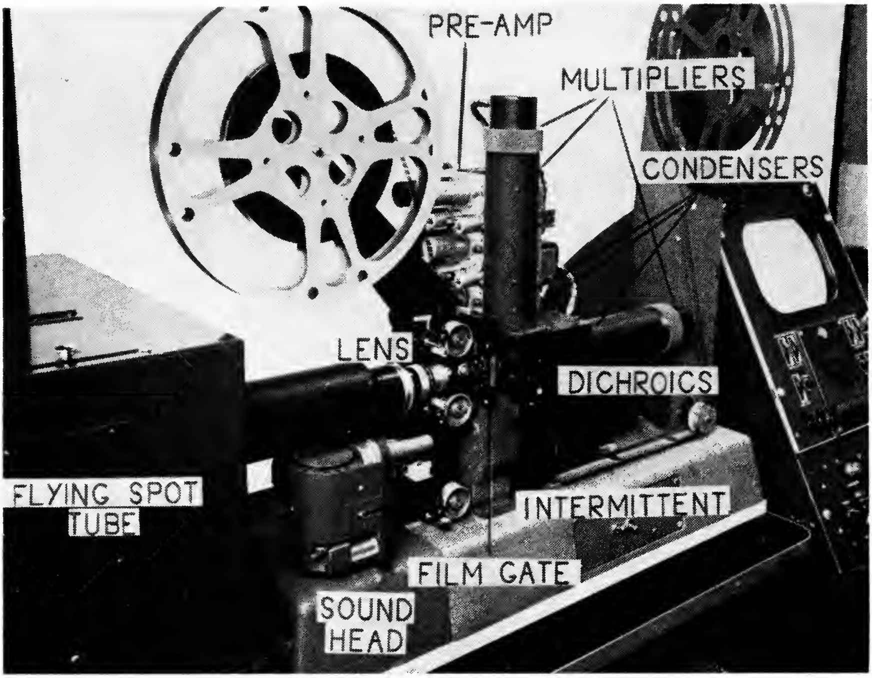

Fig. 1. The film scanner unit, embodying the fast-cycling intermittent.

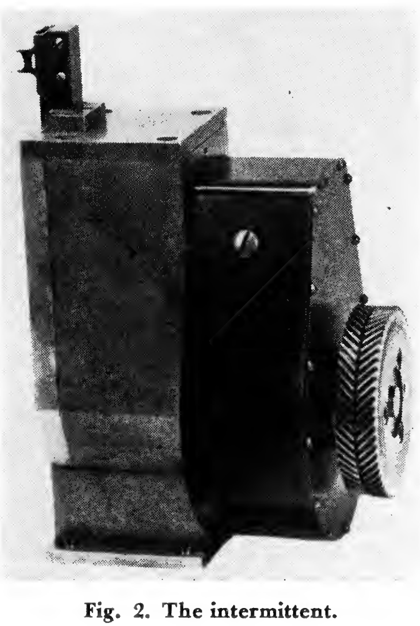

Fig. 2. The intermittent.

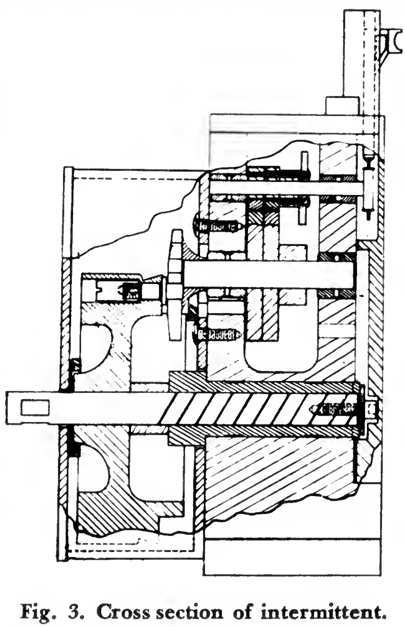

Fig. 3. Cross section of intermittent.

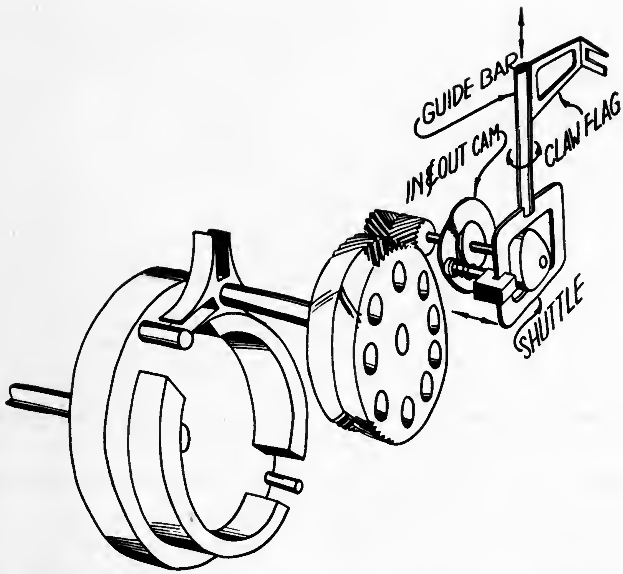

Fig. 4. Mechanical schematic of intermittent showing the Geneva and the shuttle-and-claw type intermittent coupled together with the herringbone gear train.

The Intermittent Mechanism

In essence, the mechanism is a three-pointed star Geneva coupled in series to a shuttle-and-claw type intermittent through a three-to-one step-up herringbone gear train. This can be seen from Fig. 4. The pinwheel and starwheel are of standard design taken from the Geneva used in the RCA TP-35 35mm Television Projector. The pins on the pinwheel are spaced 144° and 216° apart. Operating at 720 rpm, this spacing causes the cycling of the starwheel to be alternately at 20 and 30 cycles/sec. The weighted average of 20 and 30 is, of course, 24. This makes the cycling of the intermittent compatible with both the field rate of the television system and the frame rate of motion-picture film.

The entrance of a pin in the slot of the starwheel is the beginning of a cycle which results in a 120° rotation of the starwheel and, in turn, a 360° rotation of the camshaft. On the starwheel shaft is a nylon herringbone gear which drives a pinion one-third its size on the camshaft. Spur gearing was avoided in order to assure maximum tooth strength and the minimum tooth contact vibration. The herringbone gear was used instead of a helical gear in order to avoid end-thrust components from the intermittent loading of the gear train. Nylon was used because of the high ratio between shear strength and mass.

The camshaft carries both the in-and-out and the up-and-down cam. The up-and-down cam is a constant-diameter type fitted into a Scotch-yoke type of follower. This follower is a part of the shuttle for the claw. The guide bar for the shuttle serves as the connecting link between the claw flag and the follower. The point of attachment of the guide bar to the follower was selected so that the lateral components of the downward force are small. The in-and-out cam is a face-type cam.

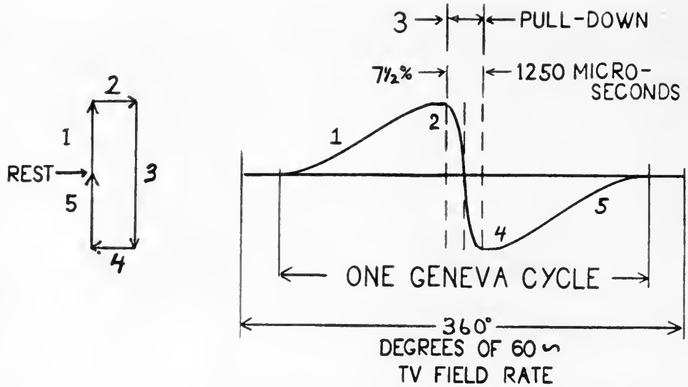

Fig. 5. Claw travel and Geneva cycle with displacement plotted against time.

The shuttle slides up and down in a slot in the spring-loaded follower and is positively controlled. This linkage of the in-and-out cam to the shuttle causes it to rotate in a plane at right angles to and about the guide bar. This action is communicated through the flag to the claw, causing it to move in and out of the film at the proper times.

Description of the Cycling

The 120° rotation of the starwheel each time the Geneva cycles is converted to a 360° rotation of the camshaft by the herringbone gear train. This brings about the following sequence of events: (1) the claw leaves its position of rest at the midpoint of its back stroke and rises to the top of its vertical travel; (2) it dwells there vertically while the in-and-out cam rotates the shuttle about the guide bar as a pivot until the flag moves the claw into the sprocket holes of the film; (3) at this instant the pull-down stroke takes place and the film is registered; (4) the bottom dwell is completed and the claw is extracted from the film; (5) the claw then returns to its position of rest at the midpoint of its back stroke, there to remain until the beginning of the next film advancing cycle (Fig. 5).

Calculations of the Pulldown Time

It is obvious that if a 110° up-and-down cam is coupled with a three-pointed star Geneva through a three-to-one gear train, pulldown time measured in terms of starwheel rotation is 36.67°. Also, if the effective ratio between the starwheel and the pinwheel is known, this time can be measured in terms of rotation of the 720 rpm or 12-cycle pinwheel. Five times this pinwheel rotation in degrees relates it to the 60-cycle field rate of the television system; 28.8° is 8% vertical blanking time.

These calculations can be made precise. The geometry of the three-pointed star Geneva (Fig. 6) is such that if the distance from the pin of the pinwheel at the time of its entrance in the starwheel slot to the center of the starwheel shaft is unity, then the radius of the pinwheel is 1.73205 and the distance from the center of the pinwheel to the center of the starwheel is 2. It is also known that the rotation of the starwheel necessary to produce the pulldown is divided equally about the midpoint of the starwheel cycle. It is seen from the above approximation that this rotation is 36.67°. Then one-half of the angle, or 18.33°, is the third thing known about the triangle formed by the lines joining the centerline of the shafts,

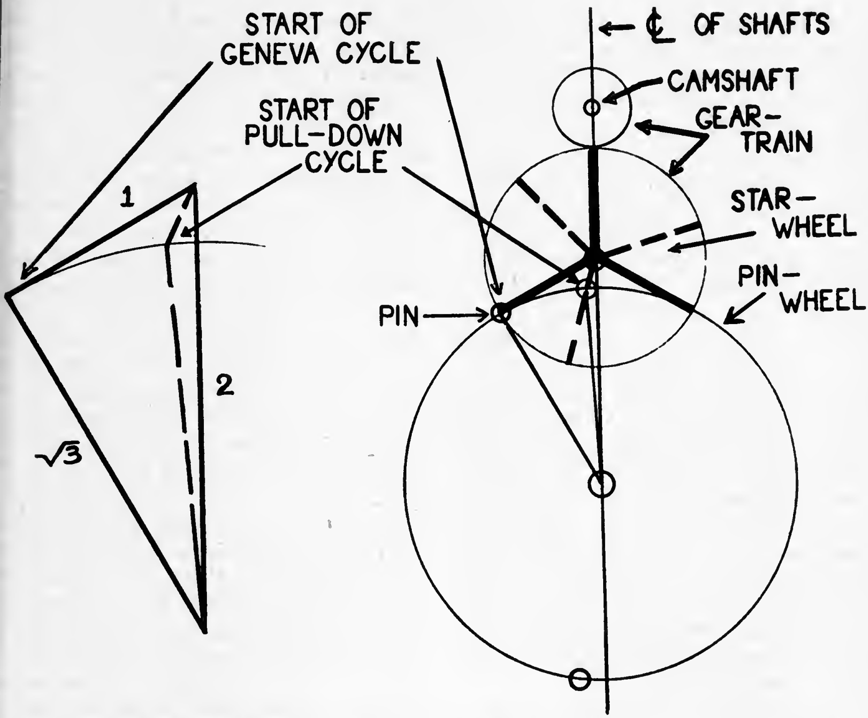

Fig. 6. The geometry of the system, showing general method of calculating the time of the pulldown stroke in terms of the rotation of the pinwheel.

the radius of the pinwheel at the beginning of the pulldown cycle, and the centerline between the pin and the starwheel shaft.

From the law of sines, the angle between the radius of the pinwheel and the centerline of the shafts is found to be 2.9650°. Twice this angle, or 5.93°, is the total time for the downward motion of the claw in terms of the rotation of the pinwheel. However, the claw is not in engagement with the film during this total time. One tooth of the claw is used as an indexing or registration pin. During the last half of the pulldown stroke, the film is allowed to overshoot the claw and be registered from the top of the sprocket hole against the uppermost side of the lower tooth.

If the intermittent is to accommodate film with 1% shrinkage, then the claw travel must be less than 300 mils. It can be only 297 mils. Otherwise, there is interference upon entrance of the claw in the sprocket holes of the next frame of film. Likewise, if there is to be no interference similarly when new film is used, the tooth that does the registering must be 3 mils less in vertical size than the sprocket hole. The vertical height of the registering tooth of the claw is 45 mils. This permits an entrance clearance of 1 mil between the top of the registering tooth and the top of sprocket hole when film with 1% shrinkage is used and 1 mil clearance between the bottom of the registering tooth and the bottom of the sprocket hole when 300-mil pitch film is used.

All of this means the claw will overtravel the film pitch from 1 to 4.5 mils. Commercial usage narrows this limit to 1.5 to 4 mils. For this overtravel, the up-and-down cam rotates from 6 to 10°. Subtracting the pinwheel rotation needed to produce this overtravel, using the smaller figures, gives a net pulldown time in terms of the 60-cycle field rate of 27.727°. This is 7.7%. In the case of film with 1% shrinkage, it is 26.595° or 7.388%.

Timewise, this can be checked from another approach. The pinwheel revolves at 720 rpm. The peak ratio between the starwheel and the pinwheel is 6.4641. The peak speed of the starwheel is then 4,654.15 rpm which is approximately constant during the middle of the Geneva cycle. The gear ratio driving the camshaft is 3. This gives a peak speed of the cam of 13,962.46 rpm. This is 232.708 rps. Pulldown takes place during 105° of this rotation; and 360 divided by 105 is 3.42857. The reciprocal of the product of 3.42857 and 232.708, or 797.856, is the pulldown time in seconds. This is 1253.3 μsec, which is the maximum time required with new film. The 7.5% vertical blanking time is one-eight-hundredths of a second or 1250 μsec; 1333 μsec is 8%.

Calculations of the Forces Involved

Once the pulldown time is known, the question of the forces involved must be considered. First, the force that is required to accelerate the mass of the shuttle can be calculated by assuming that the up-and-down cam is rotating at constant speed during the pulldown cycle. Actually, the variation in speed during the 5° of action about the midpoint of the Geneva cycle is less than one-tenth of 1%. The time is one-eight-hundredths of a second. The motion of the claw is nearly uniformly accelerated. The weight of the shuttle is less than 5 g, or approximately 0.01 lb, and the displacement is 300 mils.

Substituting in the formula which relates displacement to one-half the acceleration multiplied by time squared, the acceleration is found to be 64,000 ft/sec/sec or 2,000 times that due to gravity. The simple harmonic motion equivalent for this is nearly 8,000,000 radians/sec/sec. Substituting values in the formula for the relationship between force, mass and acceleration, the force required to accelerate the shuttle is found to be 20 lb. This figure is significant because it establishes a relationship of 1 to 2000 between the mass and the force.

The mass of the film to be accelerated, 10 frames maximum, is 239.4 mg or 0.000529 lb, and the force required to accelerate this mass is 1.058 lb. The frictional load in the gate is in the order of 2 to 3 oz or something less than 0.2 lb. The total force on the sprocket holes of the film is approximately 20 oz, and the maximum acceleration force which the up-and-down cam is required to deliver is 21.25 lb.

The torque transmitted by the cam shaft to produce this force is 5.6 lb-in. This is reflected back on the starwheel and pinwheel through the gears. The force on the pin is 68 lb. This is the maximum force required to accelerate the shuttle and the film.

The force required to accelerate the rotating parts can be determined from the rotational inertia of the parts and from their rate of acceleration. The only interest is in maximum acceleration. For the starwheel, this is 2,963.2 radians/sec/sec. The rotational inertia of the starwheel driver gear assembly is 0.005 lb-in.; that of the camshaft assembly is 0.0005 lb-in. The total maximum torque required to accelerate these parts is 19.5 lb-in. To do this, a force of 80 lb must be delivered by the pin of the pinwheel.

Sequence of the Application of the Forces

There are essentially three types of forces involved in driving this intermittent: frictional, rotational accelerating, and the shuttle accelerating forces. The heaviest frictional load in the drive is just as the pin enters the starwheel slot, because at that time the static friction of the parts must be overcome. Also at that point the velocity of the pin in the slot is maximum.

During the midrange of the Geneva cycle, the frictional load has diminished to a minimum. In fact, at the midpoint, so far as the drive is concerned, it drops to zero, for at the crossover from acceleration to deceleration there is no driving force. With this relaxation, contact pressures throughout the system are relieved.

This is also true to a lesser extent for an appreciable part of the cycle preceding and following the midpoint of the Geneva cycle. It is during this diminishing in the frictional load that the force to accelerate the rotating parts is applied. The peak acceleration for this purpose comes at 4° 46′ before the midpoint. This drops rapidly to zero for the variation in speed of the starwheel during 5° about the midpoint is one-tenth of a percent.

It is during this lull in the frictional and the rotational accelerating forces that the force to accelerate the shuttle is applied increasingly as the other two are simultaneously decreasing. Thus, the forces are staggered. It can be seen that this arrangement results in the minimization of forces, not the addition of forces, simply because one thing is done at a time, albeit in somewhat quick succession.

General Performance

After establishing the fact that the machine will operate, considerations of life are in order. The engineering models of this mechanism were based upon a Geneva that was designed and built for another service. A tribute to the adequacy of the design is its performance under loads that were not imagined during the design stage. However, its performance has given the assurance that a Geneva built for this specific duty will be completely reliable.

The operation of this mechanism can be likened to that of a high-gain amplifier. To avoid distortion, multiple stages are used. In this mechanical amplifier multiple stages are also used. The Geneva is the first stage, performing the function of a pulse former and preamplifier. The connecting gear train is a voltage amplifier and the up-and-down cam plays the part of the power-output stage.

This analogy is more significant than apparent. It points up how steep-pressure angles and attendant large concentrations of forces have been avoided. Besides that, it dramatizes the specific use of each part of the assembly. The Geneva is not used in the conventional manner. It is a pulse former. It plays no part in the final positioning of the film in the gate. It is also a speed multiplier. Since it has only a power function to perform, and since it is the first element in the system, opportunity is afforded to make it rugged enough to handle the job that has been cut out for it. It can be as massive as necessary for it operates at one-half normal speed. There is no high premium on low inertia in this stage. On the other hand, in the case of the gear train, there is a premium on low inertia and the choice of nylon is a happy one. For the up-and-down cam, only one last job remains — that of moving and positioning the film. Low mass in the shuttle is really important and the design has been left free of other functions so that small parts can be used.

Proper, if not first, regard has been given to the film. The practice of registering the film in the aperture by stopping it with friction in the gate against the propelling tooth is reversed. The film is allowed to overshoot the propelling claw and be registered from contact of the back side of the tooth against the top edge of the sprocket

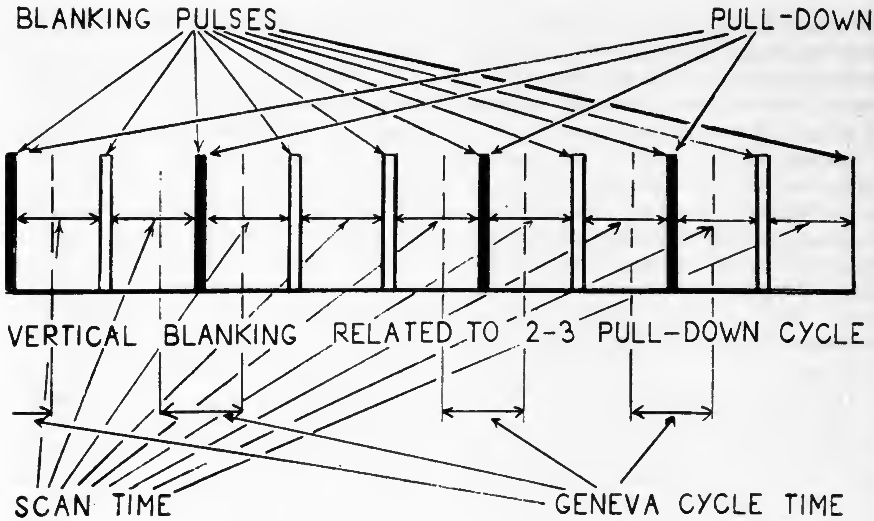

Fig. 7. The relation of the mechanical cycling to vertical blanking time.

hole. This has reduced the need for friction in the gate to that which is the result of edge-guiding and that which is necessary to insure mechanical stability. This is sufficient to prevent film from bounding back after registration. The deceleration of the claw is much greater than the free deceleration of the film. Consequently, the registering edge of the sprocket hole is in contact with the back side of the tooth long before the end of the pulldown.

Attention has also been given to film steadiness. The tooth that acts as a registration pin is solidly connected to the follower of the up-and-down cam. At the end of each stroke, the tooth figuratively sits on the same cam dwell and waits for the film to be registered against it. In the process, any unevenness of wear, or the build-up of tolerances, once-around variations, or the nonuniformity of parts plays no role. Using this method of registration means that the surface of the film is not subjected to any unusual pressures. It also means that in no case is the film in danger of damage from the claw, even when an improper loop is formed. The gate pressure is so light that the film frees itself before any damage can be done. The accelerating force of 20 oz on the film seems to be well within the operating range of forces permitted. The sprocket holes show no appreciable wear after a thousand passes. Perhaps the film, due to its plastic nature, braces itself against the quickness of this action. After all, such forces have long been encountered in film-handling equipment, particularly in the holdback sprockets against which rewind mechanisms work.

Operating noise is not an unimportant item. The operating noises of the engineering models has been little greater than that of other television film-handling equipment. However, when the mechanism is in place in its final design package, and is operating, it is hard to conceive from the resulting noise that there is a piece of film being accelerated and decelerated up to and down from 22 mph in a millisecond, 24 times a second.

General experience with units in the laboratories of RCA Victor Engineering Products Division in Camden and in the experimental color program at NBC in New York indicates that it is both possible and practical to advance 16mm film during the vertical blanking time of the television system (Fig. 7). This approach to the film-handling problem for color television preserves maximum optical speed for use by the scanner. The ability to advance the film from frame to frame in this limit of time makes possible new techniques for many uses of film in television as well as in other motion-picture applications.

Acknowledgments

Many immediate associates contributed substantially to the development of this project. Special recognition must be given the support and the collaboration of J. J. Hoehn of the Commercial Sound Section and Arnold E. Jackson of the Television Terminal Equipment Section of the RCA Victor Manufacturing Co.

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The CinemaScope Optical System

By JAMES R. BENFORD

The CinemaScope system for the presentation of motion pictures in existent theaters has resulted from major technological advances along two facets of engineering: optics and sound reproduction. The optical aspect has given rise to the wide-screen picture. The sound reproduction aspect has yielded stereophonic sound. In the consideration of the subject the optics shall be considered the dominant factor although the sound, the screen, the film and the projection equipment are to be reviewed.

CinemaScope is the name applied to the Twentieth Century-Fox wide-screen motion-picture process. The process achieves a picture twice as wide as the standard motion picture, using a single conventional camera and a single conventional motion-picture projector. The wide-angle panoramic picture is achieved by the use of cylindrical lens attachments to the camera and to the projector. The function of the cylindrical lens attachment on the camera is to compress a picture of twice the normal angular width onto a conventional 35mm film without altering the height of the picture. The cylindrical lens attachment on the projector expands this laterally compressed image, restoring it optically to a correctly proportioned picture but having twice the conventional picture width. Such a system, where the intermediate picture is distorted and then restored in the final image to a nondistorted picture, is called "anamorphic."

Presented on October 9, 1953, at the Society's Convention at New York by J. D. Hayes for the Author, James R. Benford, Bausch & Lomb Optical Co., Rochester 2, N.Y.
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The panoramic view which such an anamorphic system is capable of achieving greatly heightens the reality of the scene and increases the potential possibility of producing motion pictures for increased "audience participation." This possibility is further heightened by stereophonic sound which, by means of three separated sound amplifiers behind the screen, re-creates the direction of the sound, as it occurred in the original scene. To achieve the double-width projected image without loss of image brightness the Twentieth Century-Fox engineering staff has developed a specially embossed projection screen which, when formed into a gentle cylindrical curve, directionally reflects the light into the useful theater area, rather than allowing it to scatter at random throughout the theater.

The CinemaScope process may thus be characterized as including three major items: (1) The anamorphic compression and expansion lens attachments; (2) the stereophonic sound; and (3) the improved directional projection screen.

Historically the use of cylinder lenses to achieve wider angular coverage on film goes back to the latter part of the

19th century.[1] The general application of this idea to motion pictures was patented in this country in 1912 by Ernesto Zollinger of Turin, Italy. The problem of producing well-corrected lens designs along this line received the attention of H. S. Newcomer, of New York City, and several patents were issued to him in the period between 1930 and 1940.[2] In this same period H. Chrétien of St. Cloud, France, also produced finished anamorphic lens designs using cylindrical lens systems[3] for use as attachments for motion-picture camera and projection lenses. One of Chrétien's designs was used as a basis for the design now being produced by the Bausch & Lomb Optical Co. for the CinemaScope process.

The Chrétien design was submitted by Twentieth Century-Fox to Bausch & Lomb early this year, with the request that immediate quantity production be started. The conversion of the design to modern types of optical glass and the establishment of manufacturing tolerances and inspection standards were immediately started. At the same time, experimental equipment was obtained, and experimental lenses were produced on this equipment, in order to determine the techniques needed to mass produce accurately aligned and optically precise cylindrical lens systems. A very tight engineering and manufacturing schedule was necessitated by the pressure for production of a number of CinemaScope motion pictures in a very short time, and this schedule was met and bettered. In the early weeks of this year a number of lenses were completed and put to immediate use, and since then continuous production has kept pace with the rapidly expanding demand for these lenses.

Figure 1 shows the path of light through the anamorphic camera attachment. The top view shows how the cylindrical lens system acts like a reversed Galilean telescope in the horizontal meridian, effectively halving the focal length of the objective and doubling the field coverage. In the vertical meridian, however, the anamorphic attachment leaves the focal length and field coverage unchanged, as the cylindrical system has no lens power in this meridian. It will be evident that the anamorphic lens system must form an image in the same plane as the object, i.e., must be afocal, in order that both horizontal and vertical fans of rays shall come to a common focus, so that the system shall be free from astigmatism. To maintain this afocal property at all object distances, it is necessary to provide a focusing motion of the negative lens with respect to the positive lens. The maintenance of precise alignment of the cylinder lens axes during this focusing motion is probably the principal mechanical feature differing from conventional focusing mounts. Very precisely fitted double keyways have provided the means for maintaining this alignment.

The anamorphic projection attachments are very similar in basic form to the camera attachment, differing mainly in the relative size of the positive and negative lenses. This is simply to conform to the larger aperture but smaller angular field coverage required in projection. The projection attachments are shown in Fig. 2. The smaller form is designed to work in conjunction with the new 3-in. to 5-in. $f/1.8$ Super Cinephor projection lenses. The larger

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1. Cf. British Patent No. 1453, May 14, 1862, by Leon Farrenc.

2. British Patent 349,507, May 26, 1931; U. S. Patent 1,932,082, October 24, 1933; U. S. Patent 1,945,950, February 6, 1934; U. S. Patent 1,945,951, February 6, 1934; U. S. Patent 2,207,409, July 9, 1940.

3. British Patent 356,955, September 17, 1931; U.S. Patent 1,829,633, October 27, 1931; U.S. Patent 1,962,892, June 12, 1934; U.S. Patent 1,829,634, October 27, 1931.

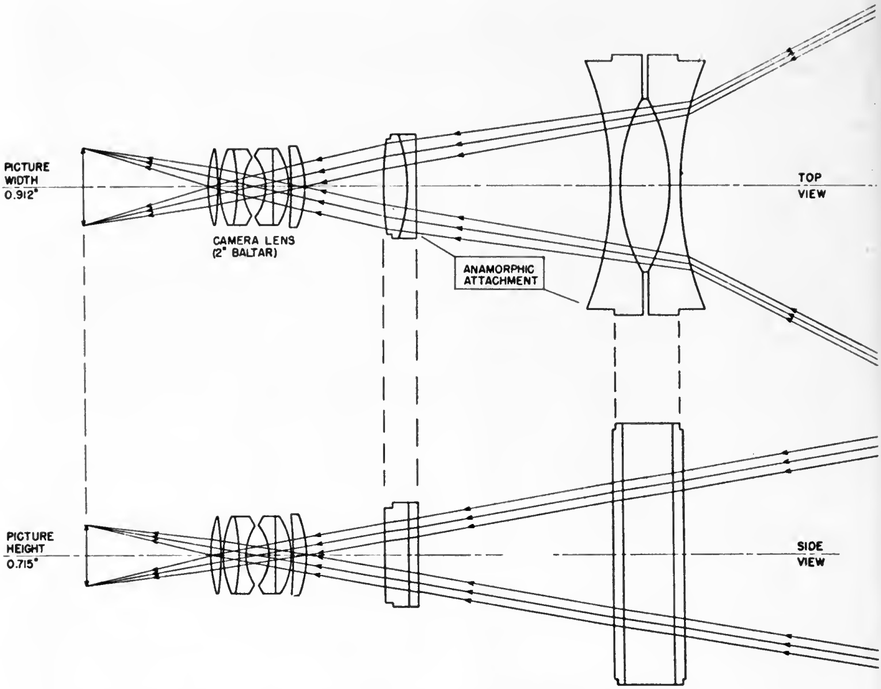


Fig. 1. The path of light through the CinemaScope camera attachment.

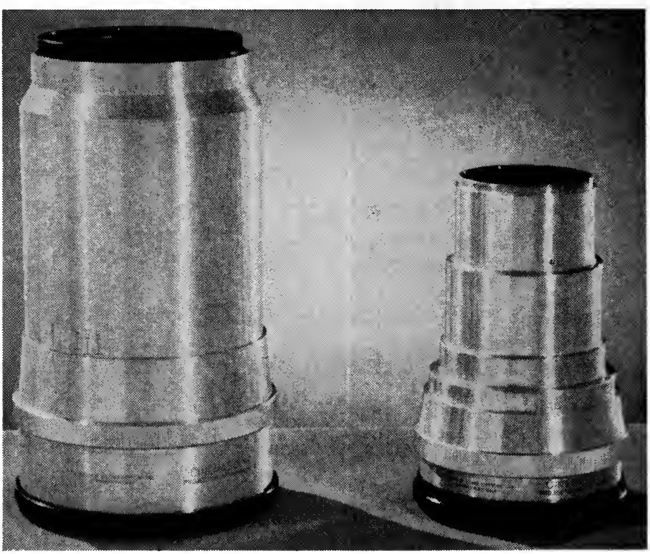


Fig. 2. The Bausch & Lomb anamorphic projection attachments for CinemaScope.

form is designed for the focal lengths over 5 in. The anamorphic attachments are provided with a focusing mechanism with a graduated footage scale, and a locking mechanism to maintain the focus at the proper projection throw. This focusing is done only once and the unit then locked at this setting. The projection lens itself is then focused to give maximum sharpness in the normal manner.

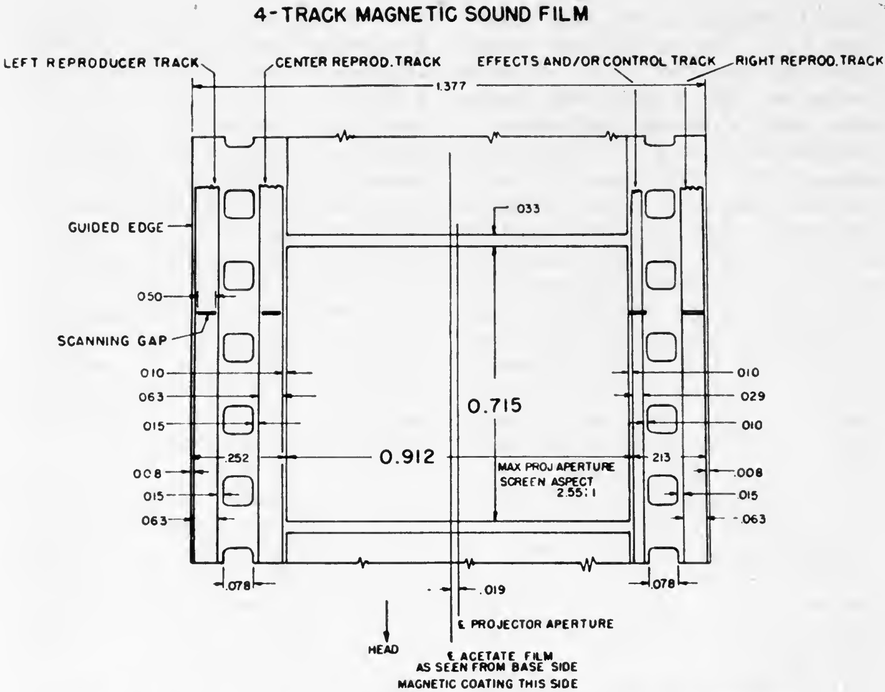
By reason of the conversion to magnetic sound tracks and the use of narrower sprocket holes it has been possible to start with a larger original frame size thereby reducing graininess to a minimum. The CinemaScope vs. the regular frame sizes are shown in Fig. 3. Both height and width of the frame have been increased. After projection the CinemaScope picture is doubled in width, so that the comparative sizes of the final projected standard and CinemaScope picture are as shown in the bottom of the figure.

The location of the sound tracks and the narrowing of the sprocket holes for the CinemaScope film are also shown in Fig. 3. The sprocket holes are located toward the outside limit of their position on standard film, so that after the sprockets in the projector have been narrowed down CinemaScope or regular film can be interchangeably projected. The narrower sprocket holes not only result in more available picture area, but also strengthen the film against wear. Figure 3 shows how much more of the film area is being used in the new process.

Figure 4 shows the relative simplicity of converting a standard motion-picture projector from conventional to CinemaScope pictures. It should be emphasized that this simplicity of conversion and the fact that only a single standard 35mm projector is used, greatly adds to the economic feasibility of the process. In Fig. 4, A represents the magnetic soundhead which is fastened permanently in place between the upper magazine and the top of the projector casting; B represents the anamorphic projection attachment which is mounted in such a fashion as to be easily removable for projecting conventional pictures. In projecting conventional pictures the magnetic soundhead is by-passed. The single-track optical soundhead is in use in this arrangement. In CinemaScope presentation the optical soundhead is by-passed, and the film threaded through the stereophonic magnetic soundhead. The three major magnetic tracks amplify respectively through the left, center and right sound amplifiers located behind the screen, and re-create the direction from which the original sound came.

The special screen developed by Twentieth Century-Fox engineering staff has an embossed surface designed to direct the reflected light into the useful seating area of the theater. It is composed of many tiny concave mirror-like elements which by reason of their relative curvature and size reflect the parallel incident beam back as a divergent beam of controlled angular extent in both horizontal and vertical meridians. Two patterns are available, a head-on pattern and a tilted pattern, the type selected being dependent on the theater construction and on whether the screen itself is tilted or vertical. A 2:1 gain in image brightness is realized with this screen.

In conclusion, it would be well to analyze the basic reasons for using anamorphic lenses in preference to conventional spherical lenses. There appear to be two basic reasons for the use of the anamorphic lenses. The first is to enable one to keep graininess to a minimum by use of the maximum useful film area, in a process where for practical considerations this can best be achieved by different aspect ratios at intermediate stages in the process. In this respect the CinemaScope process might eventually be improved by the use of a larger initial picture which can be reduced in printing to the existent



CinemaScope frame size, since most of the practical limitations on film size occur in projection, rather than in photography. The second basic reason for the use of cylindrical anamorphic lenses lies in lens design simplifications, due to the fact that a cylindrical-lens system need be corrected only for the tangential focus, since it has no lens power for the sagittal fans of rays. This simplifies the field flattening in the cylinder-lens system, since it assures the lens design the same degree of correction for curvature and for astigmatism. For this reason the cylinder system can give better field correction than the conventional spherical-lens system for the same degree of complexity of the lens system.

The CinemaScope process may therefore be summarized as a practical single-camera, single-projector process, utiliz-

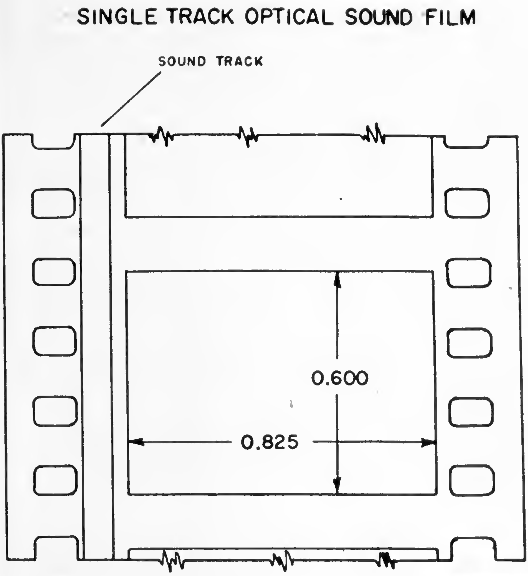


Fig. 3. Comparative size of CinemaScope and conventional frame, and comparative size of final projected image.

ing cylindrical anamorphic-lens attachments for both camera and projector, to produce a picture of twice the normal width taking fullest advantage of the available film area on standard 35mm film, combined with a curved panoramic screen with controlled reflectance to maintain optimum screen brightness, and with magnetic stereophonic sound to heighten the sensation of reality in the scene.

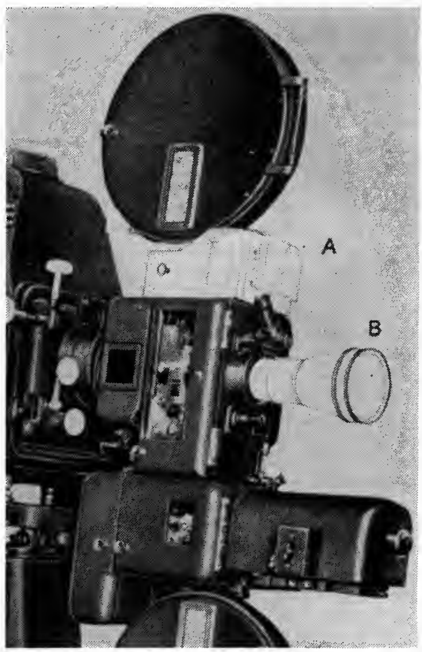


Fig. 4. Conversion from conventional projection to CinemaScope projection by the addition of the magnetic stereophonic soundhead A and the anamorphic projection-lens attachment B. (Photo Courtesy Twentieth Century-Fox.)

Acknowledgment

Messrs. E. I. Sponable and H. E. Bragg of Twentieth Century-Fox have supervised the engineering and development of the CinemaScope process in its entirety. At Bausch & Lomb the engineering and development of the lens systems has been carried out under the supervision of Dr. Howard S. Coleman. Engineering tolerances and inspection specifications have been the responsibility of A. E. Neumer. Lens design work has been carried out by Dr. N. A. Finkelstein and E. Delano. Process development work was supervised by T. J. Zak and factory engineering by W. R. Knowlton. The mechanical design was carried out by O. W. Boughton and C. DeGrave.

Discussion

Chester E. Beachell (*National Film Board of Canada*): What is the change in focal length as the angle increases out to the side in the lens?

Mr. Hayes (*who read the paper*): It's pretty nearly linear as it works its way out. In other words, right dead center we have what we call a no-power system. In the vertical direction we have a so-called no-power system. As you go directly out in the horizontal direction, your power is increasing. As we go off on the bias, we have different degrees of power. To be specific, at so many degrees from the center I don't know what is the power.

Mr. Beachell: You stated that it was possible to produce an anamorphic lens with prisms as well as cylindrical lenses. I would think that this curve would be very critical in setting up some kind of standard. If a picture were taken with this cylindrical anamorphic lens and a prismatic lens used to reproduce it, or vice versa, would the picture appear in its original proportions? That is, would the cylindrical and prismatic optics be interchangeable?

Mr. Hayes: I haven't seen any pictures of this type made with prismatic lenses but I know that some have been made. A considerable amount of work has been done on the use of prismatic lenses. They have a slight taper to them. The same effect is achieved with the use of cylindrical surfaces, as with the prisms.

Mr. Hayes: I think that they will be interchangeable, but I can't say for certain. We haven't computed the two systems.

Ben Schlanger (*Architect, New York*): I wonder if there's any information on the origin of the 2.55 aspect ratio and also is there any information as to what Chretien's original feeling was about that ratio?

Mr. Hayes: There is in one of Chretien's early patents relating to the use of anamorphic lenses a discussion of the format size. I don't recall his conclusions, but they should be in his patents in the late twenties or the early thirties.

Mr. Schlanger: What is the up-to-date basis for the selected aspect ratio, at least as CinemaScope has adapted it?

Earl I. Sponable (*Twentieth Century-Fox Corp.*): When we started to make CinemaScope pictures we placed the picture on the available width of the film and we came out with an aspect ratio of 2.66:1. At that time we made experiments going from 2.66 on down through 2.0 and 1.8 and 1.5. The people at our studio decided they liked the wide picture, the widest picture we could make. When we came along and put the sound tracks on we had to use some of the picture area, so we ended up with 2.55:1. That's how we arrived at that figure.

Denis Gillson (*National Film Board of Canada*): Are the depth-of-field characteristics of the taking lens adversely affected by the use of the anamorphic lens?

Mr. Hayes: In theory, no; in practice, it has been found that instead of using the standard focusing position, a better compromise can be found.

Mr. Sponable: I'd like to give a practical answer in that the depth of field is increased by the use of the anamorphic lens. We have some recent pictures made in Venice in which the depth of focus is simply amazing. It seems to go on, and on, and on. I think that theoretically it's increased about twice, isn't that right, Mr. Hayes?

Mr. Hayes: Somewhat. It's increased in the horizontal direction by virtue of the short focal length. You would get a peculiar ellipsoid if you tried to plot the depth of focus in the two directions.

Stereophonic Tape Recording Equipment

By RUSSELL J. TINKHAM

Electrical phasing, time phasing and balanced loudness between channels are necessary for the maximum realization of the benefits of a stereophonic recording system. Elements and characteristics of two- and three-track recording and reproducing systems are briefly described.

AMPEX began the commercial production of multitrack tape recorders about four years ago for those interested in recording telemetered information from guided missiles and the like. These equipments provide any number of simultaneous channels up to 14. It was a simple step, therefore, to make stereophonic tape recorders with two or more channels.

After reviewing the literature, and our prospective customers' needs, we have built both two-track and three-track machines. The two-track units have been used primarily in the industrial field for the purely investigative purposes of localizing and subjectively analyzing sound sources, or making sounds subjectively appear more realistic. Two headphones, rather than two speakers, are generally employed. One track often is used also for quantitative measurement, while the other is used for running commentary. The three-track units have been used primarily where sound is to be reproduced by means of a loudspeaker system. Obviously with three-track equipment it is possible to use only two tracks if headphones are preferred.

In the case of loudspeakers, listening-room acoustics are all-important, and must be taken into consideration, but this matter is beyond the scope of the present paper.*

In recording multichannel sound for later reproduction, we have not only verified all the findings of the Bell Laboratories' experiments of 20 years ago, but also we have run into one other problem. Since the Bell Laboratories' experiments were all concerned with instantaneous transmission of the original sound, time-lag effects between channels were not factors. Normal time lags are desirable. A recorder, basically, is a time-storage device. In delaying time all the channels must be delayed by the same amount, and, since they are all recorded side by side on the same tape, it might be assumed they must all be

Presented on May 1, 1953, at the Society's Convention at Los Angeles by Russell J. Tinkham, Ampex Electric Corp., 934 Charter St., Redwood City, Calif.
(This paper was first received on September 1, 1953, and in revised form on December 9, 1953.)

* R. J. Tinkham, "Binaural or stereophonic?," *Audio Eng.*, *37*, *No. 1:* Jan. 1953.

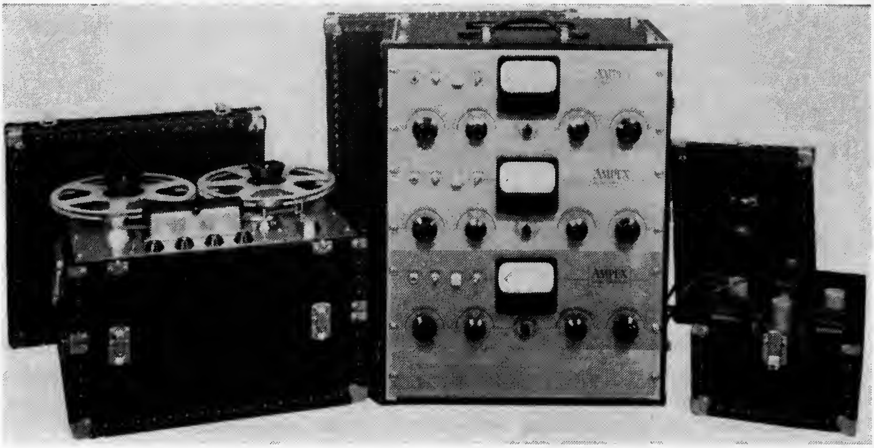


Fig. 1. Complete 3-channel stereophonic recorder

reproduced at the same time. That is what was thought at first, but it was found that while all of the heads were side by side, any deviation of spacing longitudinally with respect to the direction of tape motion introduced small constant time differences between channels.

This has the effect of making the apparent location of a given source, when reproduced, deviate from its actual original position. The angle of deviation increases as the time differential increases, and can be calculated. Therefore, all the heads must have the smallest possible error in parallel alignment. Some manufacturers use the same heads for both recording and reproducing. Here, obviously, there is no time error. But should such a recording be played on another machine, the head spacing cannot be different from the first without running afoul of this time-phase shift.

This equipment uses two separate sets of heads and amplifiers; one set for recording, and one for playing back the same record an instant after it has been made. This method has obvious monitoring advantages during the recording of a program, and it involves the difficulty for the manufacturer of making it necessary to build high accuracy into the head spacing. This problem and the one of inductive cross-talk between adjacent channels (30+ db) have been worked out.

Description of Equipment

The two- and three-track (Fig. 1) Ampex systems are housed in three luggage cases. One case contains the mechanical equipment involved in tape motion, the second contains the requisite number of combined record-playback amplifiers, each with separate controls and meter. The third case contains the power supplies for the amplifiers. All parts, optionally, may be mounted in a standard 19-in. rack.

The new Series 350 Ampex mechanical assembly (Fig. 2) is mounted on a $15\frac{3}{4} \times 19$-in. panel. Each reel turntable is driven by its own torque motor, and each motor is equipped with a solenoid-actuated brake, self-energizing in the proper direction.

A ball-bearing mounted flywheel, driven by the passage of the tape around a drum mounted on the same shaft and above the panel, stabilizes the tape motion as it approaches the head

Fig. 2. Mechanical assembly, 3-channel stereophonic recorder.

Fig. 3. Single record-reproduce amplifier. One is used for each channel.

assembly. The head assembly holds, from left to right, the full-track erase head, the two- or three-track recording head, and the two- or three-track playback head. The heads are suitably shielded in mu-metal cans, with covers which fall into place as the hinged portion of the assembly is lowered into place, after tape threading. The tape is accurately guided onto and off the heads by means of Pyrex glass guides spaced the width of the tape apart, and approximately at the entrance and exit of the assembly. The tape is pulled over the heads by means of a pinch drive consisting of a capstan and rubber capstan idler roller. The capstan is the accurately ground shaft of a dual-speed hysteresis motor, and is capable of driving the tape at either $7\frac{1}{2}$ in./sec or 15 in./sec with a timing accuracy of ± 3.6 sec in 30 min of recording time. $3\frac{3}{4}$-in. or $7\frac{1}{2}$-in. machines are also available.

The capstan motor is equipped with a flywheel, and speed is changed by a toggle switch. All mechanical functions — fast forward, fast rewind, stop and playing speed forward — are controlled by means of momentary contact pushbuttons. Electrical memory is furnished by d-c actuated relays. Therefore, the entire Speed Lock* equipment may also be plugged into the mechanism to make possible the synchronizing of the equipment with motion-picture camera and projector equipment to within 0.001-sec accuracy. This is an electrical arrangement and requires no additional heads or mechanical modification to the equipment. This synchronizing device may be used with any recorder without mechanical change. Only electrical connections need be made.

Each separate amplifier channel (Fig. 3) has both recording and reproducing amplifiers, with appropriate switching, so that either the incoming signal on that channel, or the signal just recorded on the tape for that channel, may be monitored. Each standard 4-in. (vu) meter may also be switched between the recording amplifier and the playback amplifier. Erase and bias voltages for each channel may also be read on this meter through appropriate switching. The recording amplifier has a choice of three inputs: low-impedance microphone, balanced, and unbalanced bridge input. The playback amplifier delivers +4 vu across a balanced or unbalanced 600-ohm line output, and an internal 600-ohm load resistor may be cut in or out by means of a switch. Suitable gain controls are provided for each input and output. Erase and bias current is obtained from a push-pull oscillator using a toroidally wound coil and is tuned to approximately 100 kc. This oscillator is mounted integrally on one of the amplifiers and its output is fed to separate buffer amplifiers associated with each of the other channels. This eliminates the possibility of beats which would exist if each channel had its own oscillator.

The power supplies are straightforward. They are mounted separately to reduce hum pickup and to divide the weight into convenient packages.

On the three-track system the tracks are each 0.040 in. wide and are separated by blank tape space of about 0.050 in. All three tracks lie side by side on standard $\frac{1}{4}$-in. tape. With such narrow tracks, some signal-to-noise ratio is sacrificed (55 db overall achieved). A restricted bandwidth would give less background noise. While it has been stated that we can tolerate a more restricted bandwidth, when using multitrack reproduction to get the same subjective feeling of presence as compared to a monaural system, it is also true that the full auditory bandwidth will give even more realism to the sound.

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* Walter T. Selsted, "Synchronous recording on $\frac{1}{4}$-in. magnetic tape," *Jour. SMPTE, 55:* 279–284, Sept. 1950.

Stainless-Steel Developing-Machine Rollers

By A. H. VACHON

A NEW LIGHTWEIGHT stainless-steel developing-machine roller for 16mm and 35mm film has been devised by the Engineering Division of the National Film Board of Canada. The rollers are manufactured and supplied by The Ketchum Manufacturing Co., Ltd., P.O. Box 388, Ottawa, Canada.

Stainless-steel rollers were developed in order to eliminate the disadvantages encountered with the usual composition rollers, namely the difficulty of cleaning and the wear caused by cleaning and handling. At the National Film Board, the use of stainless-steel rollers has practically eliminated the need for replacements.

The roller is made from 26-gauge stock and composed of four separate parts. Two identical sides and two identical bearing cups are spot-welded into one finished unit. Figure 1 is a design drawing of the complete roller. Various stages of blanking and forming the material are shown in Fig. 2. Figure 3 is a completed side coming off the press. Figure 4 shows an actual bank of rollers which have been in operation on one of our developing machines.

The individual rollers weigh approximately $2\frac{1}{2}$ oz, are easy to clean, and pick up very little foreign matter. The National Film Board has put about 500 of these rollers into use over the past 18 months and has found their performance superior to that of any rollers previously used.

Presented on October 6, 1953, at the Society's Convention at New York by A. H. Vachon, National Film Board of Canada, 35 John St., Ottawa, Canada.
(This paper was received Nov. 28, 1953.)

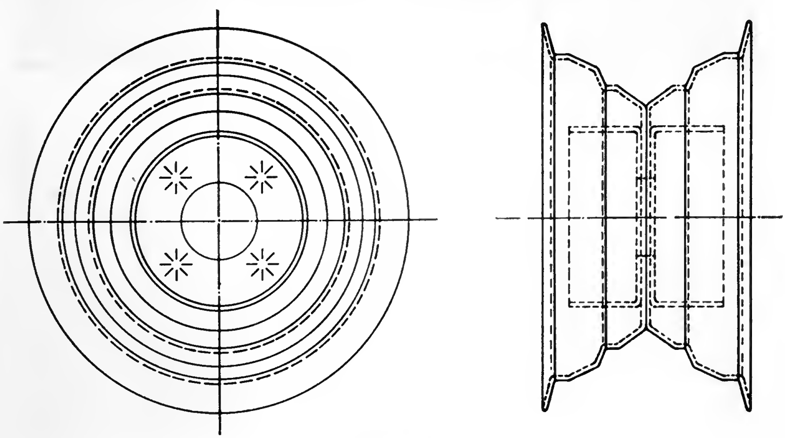

Figure 1

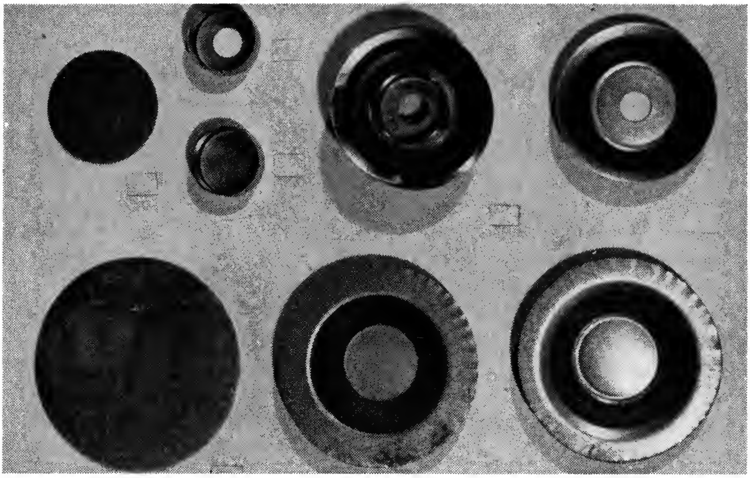

Figure 2

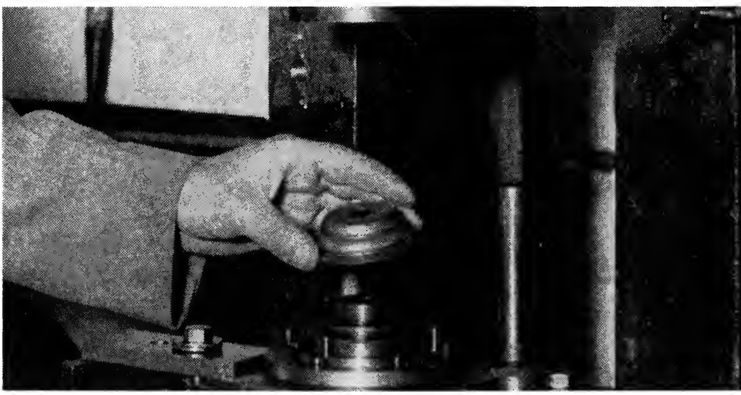

Figure 3

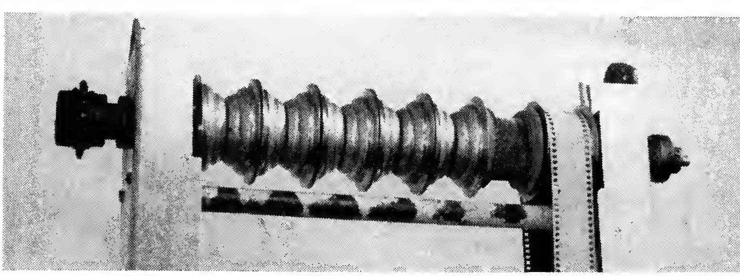

Figure 4

Use of the 16mm Sound-Service Test Film — SPSA

By WILLIAM C. EVERS

Among the many specialized duties which confront every audio-visual director is that of maintaining high-quality performance of projection equipment. Because the typical director does not have the time or the inclination to become an electronics engineer or repairman, which he needs to be if he does much work with a sound projector, he needs some objective means of judging the quality of performance or diagnosing trouble.

Here is where the various test films available from the Society of Motion Picture and Television Engineers help the audio-visual director. With these he can check to see that a projector is performing up to standard, or that a service man has repaired a projector competently. Incidentally, some of the better service agencies are using these films to aid in locating the cause of trouble, as well as to double-check work before returning the equipment to the customer.

One film which combines tests of the accuracy needed to take much of the subjectivity out of projector testing and establish it on an objective basis is the *16mm Sound Service Test Film*.* Properly used and interpreted, the film will determine whether poor sound is the fault of equipment performance and the nature of the trouble, if it is in the projector. The description of the film which follows is based on the manual provided by the producer.

The different technical test sections will be presented in the following order: sound-focusing test for checking the position of the sound lenses so that the scanning beam from the exciter lamp will be in sharp focus on the sound track; the buzz-track test for making certain that the sound track is in the proper lateral position as it moves around the sound drum; and a frequency-response test which presents tones of twelve different frequencies for ascertaining whether the sound system reproduces both high and low frequencies in a satisfactory manner. In addition to the three technical sections, there are four sections for testing title music, dialog, piano music, and orchestral music — all of which have been recorded with great accuracy and care. These sections are also useful for checking room acoustics. A comparison of a projector's sound quality in rooms of various sizes will reveal differences in acoustics.

Instructions for the use of this film and its interpretation are discussed below. Captions projected on the screen while the film is being run describe the sound being presented and criteria for evaluating it.

Title Music. The orchestra music in this section contains both high- and low-frequency tones. If the sound system is adjusted properly, the tones are clear

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A contribution by William C. Evers, Supervisor, Audio-Visual Center, Indiana University, 1804 East Tenth St., Bloomington, Ind.; reprinted here from the *Bulletin* for February 1953 of the Indiana University Audio-Visual Center.

* Can be purchased for $18.00 from the Society of Motion Picture and Television Engineers, 40 W. 40 St., New York 18. Also available on a rental basis from the Audio-Visual Center, $2.00 for one to five days' use.

and full. The sound is crisp and without the shakiness of tone called "flutter."

Sound-Focusing Test. This section determines whether the sound-track scanning beam (that beam of light from the exciter lamp which is focused on the sound track by means of the sound lenses) is correctly focused upon the sound track. Correct adjustment here is indicated by maximum loudness of tone from the speaker. This test is especially pertinent for those projectors that have a fidelity lever which can be used to move the sound lenses into sharper focus. For projectors not having a fidelity lever it is recommended that a careful shop adjustment be made, if by using other tests it appears that the scanning beam is out of focus. This section of the test is 15 ft in length, with a 5000-cycle square-wave track, and will run for about 25 sec.

Buzz Track. In this test no sound is good sound, since a projector in proper adjustment will reproduce no sound at all. This will indicate that the scanning beam is properly aligned and that the film does not weave from one side to the other. Along each edge of the sound-track and just outside the sound-track area a tone has been recorded. On the edge nearer the edge of the film, a 1000-cycle (high) tone is recorded; on the edge nearer the picture area there is a 300-cycle (low) tone. Therefore, if the guides which position the film laterally are out of adjustment, one tone or the other will be heard. If the 1000-cycle tone is heard, the scanning beam is too near the edge of the film; if the 300-cycle tone is heard, the beam is too far from the film's edge and too near the picture area. Adjusting the film guides laterally should eliminate both tones. When both tones are heard, the scanning beam is not focused at the proper distance. An indication that the film is weaving at the sound drum is given when first one tone, then the other, is heard.

Frequency Response. This section will enable the listener to evaluate the frequency response of the projector. There are 12 different frequencies recorded, each of which runs for about 10 sec. Following are the steps in utilizing the section. While a 400-cycle tone is being reproduced, the tone control should be set at normal and the volume adjusted to a comfortable listening level. Following the 400-cycle tone are the following, each for a duration of approximately 10 sec: 50, 100, 200, 300, 500, 1000, 2000, 3000, 4000, 5000 and 6000 cycles. Immediately after the 6000-cycle tone, there is again a 400-cycle tone, which serves as a volume-level check. It should be of the same volume as the initial tone.

All tones in the series should be clearly heard and none should be too loud. If this is not the case, the projector is not functioning properly. If it is apparent from the sound-focusing and buzz-track sections that the sound optical system is in proper adjustment, failure in this test indicates trouble in the amplifier or loudspeaker system.

Dialog. Since many educational films are of the narration type, this is a valuable section. It is an example of good recording, with the quality of sound surpassing the visuals. If the loudspeaker is properly placed in relation to the screen there will be the feeling that the actors are in the room with the audience and that the spoken words are actually coming from their mouths. This section is also especially valuable for evaluating acoustical situations.

Piano Music. Film audiences often wonder whether unsatisfactory sound which sometimes results from the use of piano music in the sound track is due to the projector or whether it is due to an inferior sound recording. This section is accurate and reproduces the high and low tones well without a noticeable flutter or waver on the sustained notes. Failure in the test — that is, fluctuation in the sound — is an indication that the film is passing the sound scanning beam at a varying rate of speed.

Orchestral Music. This section should be played without increasing the volume in order to hear certain passages or decreasing it to listen to other passages comfortably. The various passages should reproduce with both the high and low frequencies clearly audible and without distortion.

The Society of Motion Picture and Television Engineers' catalog lists other test films which are available at nominal cost. The *16mm Sound Projector Test Film* is often used by equipment dealers to demonstrate the performance of their equipment; the *Multifrequency Test Film*, to obtain the electrical-frequency response at the output of the power amplifier; the *Buzz-Track Test Film*, to check the placement of the scanning beam; the *Scanning-Beam Illumination Test*, to check the eveness of light across the width of the sound track; the *Sound Focusing Test Film*, to focus the sound optical system of the projector; the *3000-Cycle Flutter Test Film*, to measure the flutter introduced by 16mm sound reproducers; and the *400-Cycle Level Test Film*, to furnish a standard of recorded signal level for use in measuring the effective amplification and sound output of 16mm projectors.

It is obvious that some of these films are for the purpose of making adjustments and actually servicing the sound system of projectors in situations where an output-meter is available; therefore the director probably will not use them as often as will his service man.

British Standard 1404 : 1953 — Screen Luminance (Brightness) for the Projection of 35mm Film

By W. WALLACE LOZIER, *Chairman*, SMPTE Screen Brightness Committee

Publication of this standard in May 1953 revises the original one issued in 1947. The text of the Foreword, Specification and Appendix A is reprinted below. The complete text of the Standard also includes: Appendix B, "Report on the Tests Which Formed the Basis of the First Edition (1947) of This British Standard"; Appendix C, "Report on Tests Made to Provide Data for the 1953 Edition of B. S. 1404"; and Appendix D, "Notes on the Method of Measurement Specified in Appendix A."

Appendix B reports the results of viewing tests of 35mm motion pictures under controlled conditions at various screen-brightness levels and the considerations which led to the 1947 Standard brightness limits.

Appendix C reports the results of a recent series of measurements of screen brightness and related factors in 33 British theaters.

Appendix D cites the reasons for the choice of the specified type of meter and method of measurement.

Interesting supplementary comments on this British Standard are given in "Some

Notes on the British Standard of Screen Luminance" by F. S. Hawkins, *Brit. Kinemat. 23:* 43–45, Aug. 1953.

The British Standard is considerably more inclusive than the American one ("Revision of Screen Brightness Standard," *Jour. SMPTE, 58:* 452, May 1952; and "American Standard Screen Brightness for 35mm Motion Pictures," *Jour. SMPTE, 60:* 630, May 1953). The British Standard contains a specification of variation of brightness across the screen and the method of measurement in addition to the recommended level of brightness at the center of the screen. Some of these subjects are still under consideration in this country and are not included in the American Standard.

The following table shows the comparison of specified brightness at the center of the screen contained in the current American, British and French Standards. It is interesting to note that all three countries have arrived at approximately the same brightness range.

	Foot-Lamberts at Center of Screen		
	Nominal	*Minimum*	*Maximum*
American Standard PH22.39-1953...	10	9	14
British Standard BS 1404:1953...	—	8	16
French Standard NFS 27-003*....	10.2	7.3	14.6

* Specified French photometric units have been converted to foot-lamberts.

British Standard Specification for Screen Luminance (Brightness) for the Projection of 35mm Film

FOREWORD

The British Standard for screen brightness, prepared under the authority of the Cinematograph Industry Standards Committee, was first issued in 1947. It recommended a range of screen brightness, measured normal to the centre of the screen, for the projection of 35 mm. colour and black and white film, and recorded the results of the comprehensive series of investigations which had been carried out in order to provide data for the establishment of this recommended range.

It was then envisaged that experience would enable a more precise standard to be laid down in a future edition, and that later it would also be found possible to specify the method of measurement.

Since the first edition was published, further comprehensive investigations have been made, both in regard to the actual range of luminance with particular reference to the position of the viewer in the auditorium, and also in regard to methods of measurement.

This revision is more specific in regard to the value of screen luminance, which now has to lie within a specified range as measured on a horizontal axis both at the centre and sides of the screen, and as seen from any seat in the auditorium, and it also specifies a standard method of measurement. It is intended to be applicable to the type of screen with black masking which is in general use at the present time.

The appendix to the first edition, which recorded the earlier investigations, is reproduced, and a further appendix, giving a report of the investigations made since, is also included.

To conform to modern terminology, the expression 'screen luminance' has been adopted in place of 'screen brightness.'

SPECIFICATION

Scope

1. This British Standard relates to screen luminance (brightness) for the projection of 35 mm cinematograph film.

Screen Luminance (Brightness)

2. The luminance (brightness) of the screen, measured from any seat in the auditorium by the method and under the conditions specified in Appendix A, shall be as follows: The luminance of the centre shall be not less than eight foot-lamberts and not more than sixteen, and the luminance of each side measured on the horizontal axis shall lie between 0.6 and 0.75 times the measured luminance at the centre, and shall preferably be as near as practicable to 0.7.

NOTE 1. For the purposes of this specification, the 'side' is defined as a position on the horizontal axis of the screen, 5 per cent of the width of the screen inwards from the edge.

NOTE 2. It has been observed that a greater variation in the ratio of side to centre luminance is tolerable with colour film than with black and white film. It has nevertheless been found that under general cinema conditions a ratio of 0.8 or greater is uneconomically achieved and tends to reduce the artistic quality of the projected picture by reason of a reduction of its apparent brillance, and that a ratio of 0.55 or less is undesirable because of an objectionable falling off of the luminance of the sides and corners, with a consequent reduction in the artistic quality of the picture.

APPENDIX A

Conditions and Method for Measuring Screen Luminance

1. Conditions of Measurement

The measurement of the luminance of the screen shall be made under the following conditions, which shall remain constant throughout the complete series of measurements.

a. The projector shall be running under normal operating conditions, with no film in the gate.

b. The optical system shall be aligned so that the area of maximum luminance is at the centre of the screen.

c. The lighting in the auditorium shall be that normally used when a film is being projected.

2. Photometer

The screen luminance shall be measured with a visual photometer in which the screen or a suitable part of it is viewed through a small telescope, which has centrally in its field of view a small comparison spot, obscuring not more than 1° of this field. The comparison spot is illuminated to a sensibly uniform luminance by a small electric lamp, the luminous intensity of which can be adjusted so as to be maintained constant. The luminance of the comparison spot is to be capable of variation by suitable means, e.g. neutral wedges, so as to be made to match that of the screen whose luminance is required. The illumination of the comparison spot by the small lamp is kept constant, and means are provided to ensure that this is achieved. The device which alters the luminance of the comparison spot is calibrated so that the luminance of the spot, and hence that of the screen with which it is matched, can be determined.

The photometer shall be capable of measuring down to 0.2 foot-lamberts and the error in the indication of the instrument at any point within the effective range shall not exceed 20 per cent of the indication.

NOTE. Information as to where such instruments can be obtained is available on application to the Director, British Standards Institution, 24 Victoria Street, London, S.W.1.

3. Number of Measurements

At least four measurements of the luminance of each selected portion of the screen shall be made from each selected position in the auditorium. The mean value of these four measurements shall be regarded as the measured luminance of that portion of the screen as viewed from that position in the auditorium. If more than one observer takes measurements, then each observer shall make the same number of observations, which shall be not less than four for each observer.

Theater Engineering Committee Report

By BENJAMIN SCHLANGER, Chairman

THE SMPTE SENT theater owners a screen questionnaire dated May 25, 1953, that was designed to help the industry determine how much larger most theater screens could be made and also what limits on picture aspect-ratio accommodation are fixed by physical conditions in the theaters. Out of 370 questionnaires returned, 330 had sufficient data to be useful in the study that is reported here.

Because the number of theaters represented is so small, the results actually show a number of typical situations that do not necessarily align with any national averages that might have been drawn, had most theaters in the country been included. But the value of the information derived should not be minimized on this score.

It is desirable to compare the number of surveyed theaters in certain categories with the number of theaters in those same categories throughout the United States. To make this possible, theaters were considered as falling into three groups; those with up to 500 seats being the first group, the second group to include those with 500 to 1500 seats and the third group those with 1500 seats or more. The percentage of surveyed theaters in these groups and the actual percentage of U.S. theaters falling in the same grouping are as follows:

Group	% *Theaters Surveyed*	% *Theaters in U.S.*	
Up to 500	18	51.9	According to statistics obtained from MPAA
500–1500	46	42.5	
Over 1500	36	5.6	

Although the sample includes information on a disproportionate number of large-circuit theaters and large-seating capacity theaters and in consequence, theaters in densely populated areas, it was felt that much worth-while information was still to be derived because the percentage of surveyed theaters that fall in the middle group of from 500 to 1500 seats differed from the percentage of this group in the whole United States by only a few percent.

Referring to the accompanying tabulation, column 1 shows the average maximum viewing distances that were found in this survey. In the first group the average maximum viewing distance is about 80 ft; in the second group, about 103 ft; and in the third group this distance is about 120 ft. The range in the latter group is quite wide, however, the lowest distance being about 100 ft and the highest being about 180 ft. This factor of viewing distance is very important because it helps to determine picture size or, stated in other terms, minimum angle subtended in viewing motion pictures from the back row. This information will also be helpful in reaching conclusions in relation to picture aspect ratio.

The survey also supplied valuable information on average picture height available. This is a key figure, which will have influence on the determination of an optimum picture aspect ratio. In column 2, in the smaller theater group, the average picture height available is a little under 15 ft. In the second grouping (of 500 to 1500 seats) the average picture height is about 19 ft, ranging from a low of 16 ft to a high of 23 ft. In the third group, the height does not increase as much as one might expect, the average height being only 21½ ft, or only about two feet more than in the group of theaters between 500 and 1500 seats. This limitation is due, in the latter group of large theaters, mostly because of the overhang of balconies. Most of these theaters have balconies, causing this restriction of view of increased screen height. These large theaters were patterned after the old stage theaters where the trapeze act set the

Presented on October 9, 1953, at the Society's Convention at New York by Benjamin Schlanger, Theater Consultant, 35 W. 53 St., New York 19, N.Y.

SMPTE Indoor Theater Survey Data.

Seating Capacity	1 ft	1 in.	2 ft	2 in.	3	4	5 ft	5 in.	6 ft	6 in.	7 ft	7 in.	8 ft	8 in.	9 ft	9 in.	10	11	12
Up to 300	77	5	13	7	1.5	Less than 38 ft available	25	10									9		
301 to 400	79	3	14	6	1.77		26	5	80	4	26	9	14	8	26	5	22	60	51.9%
401 to 500	82	6	15	2	1.87		27	6									29	18%	
501 to 600	83	5	16	0	1.91		27	10									21		
601 to 700	84	7	18	8	1.81		28	2									17		
701 to 800	91	4	18	8	1.87		30	5									20		
801 to 900	84	2	18	0	1.88		28	0									15	154	42.5%
901 to 1000	95	0	19	0	1.94	1.85	31	8	102	7	34	10	19	2	34	6	26		
1001 to 1100	106	11	20	0	2.00	1.80	35	5									11		
1101 to 1200	107	4	19	10	2.27	1.97	35	9									11	46%	
1201 to 1300	106	9	21	4	2.25	1.84	35	4									10		
1301 to 1400	112	6	21	8	2.10	1.79	37	6									11		
1401 to 1500	107	0	22	9	2.16	1.78	35	7									12		
1501 to 1600	104	0	20	10	2.14	1.80	34	8									13		
1601 to 1700	106	0	22	0	2.30	1.79	35	4									14		
1701 to 1800	120	2	22	2	2.23	1.78	40	0									16		
1801 to 1900	105	11	20	6	2.16	1.86	35	4	120	4	40	6	21	6	38	8	9	120	5.6%
1901 to 2000	113	2	20	5	2.06	1.88	37	9									8		
Over 2000	129	9	21	8	2.19	1.77	43	4									60	36%	

(1) Average maximum viewing distance
(2) Average picture height available
(3) Aspect ratio for maximum picture height & width available
(4) Aspect ratio for maximum picture height available and proposed maximum of 38-ft picture width
(5) Picture width on 3W basis
(6) Average maximum viewing distance by groups
(7) Average picture width on 3W basis by groups
(8) Average picture height available by groups
(9) Average picture height available by groups used to give picture width for 1.8 to 1 aspect
(10) Number of theaters
(11) Number of theaters by groups and percentage of total survey
(12) Percentage of total number of theaters in U.S. for same grouping

height limitation to about 20 ft above the stage floor.

The next compilation of figures that might be of interest is available aspect ratio. The maximum height and maximum width available indicate the following aspect ratios. In the first group the aspect ratio ranged from 1.5 to 1.87:1.00. In the second group the aspect ratio ranged from a low of 1.81 to a high of 2.27:1.00, the average being about 1.9:1.00 in this latter group. In the group of 1500 seats and over, the low aspect ratio was 2.06:1.00 and the high 2.30:1.00. If an aspect ratio greater than the average (and the average in these very large theaters is about 2.2) were desired, a sacrifice in the height of the picture would have to be accepted.

In column 4 is an interpolation of what would happen to aspect ratio, if all the available height and an arbitrary maximum width of 38 ft were to be used. The 38-ft maximum was chosen because greater magnification of picture image from 35mm film will show disturbing film grain. The average maximum aspect ratio under these conditions comes close to 1.8:1.00.

Discussion

Morton D. O'Brien (*Assistant Director, Projection and Sound, Loew's Theaters*): In making your computations did you base them on the fact that every seat in the theater was available at these ratios and these sizes of screens or did you incorporate a loss of a certain amount of seats in these theaters?

Mr. Schlanger: The interpolations made in this analysis were based on the assumption that all existing seating would remain in use, but knowing that there would necessarily be some existing seats nearer the screen that would be less desirable with bigger screens.

William A. Shurcliff (*Polaroid Corp.*): Do I understand that over half the theaters in the country then cannot accommodate an aspect ratio more than about 1.9 unless they cut down the height?

Mr. Schlanger: The survey indicates that this may be so.

Standards PH22.5, —.12 and —.93 Related to 16mm and 35mm Low-Shrink Film

Three American Standards, approved by the American Standards Association on December 17, 1953, are published on the following pages. Two (PH22.5-1953 and PH22.12-1953) are revisions of previous standards; PH22.93-1953 is a new standard. These three standards were published previously for trial and comment, and the background information on their development and processing will be found in the December 1952 *Journal*.—*Henry Kogel*, Staff Engineer

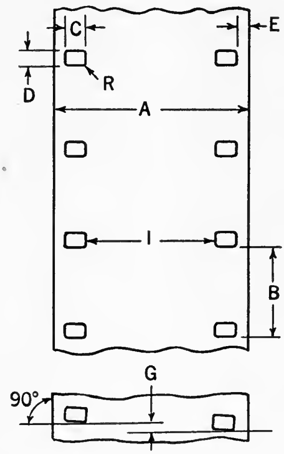
American Standard

Dimensions for 16mm Film, Perforated Two Edges

ASA
Reg. U.S. Pat. Off.
PH22.5–1953

Revision of Z22.5–1947
*UDC 778.5

Page 1 of 2 pages



Dimensions	Inches	Millimeters
*A	0.629 ± 0.001	15.98 ± 0.03
†B	0.3000 ± 0.0005	7.620 ± 0.013
C	0.0720 ± 0.0004	1.83 ± 0.01
D	0.0500 ± 0.0004	1.27 ± 0.01
*E	0.036 ± 0.002	0.91 ± 0.05
G	Not > 0.001	Not > 0.025
I	0.413 ± 0.001	10.490 ± 0.025
‡L	30.00 ± 0.03	762.00 ± 0.76
R	0.010	0.25

These dimensions and tolerances apply to negative and positive raw stock immediately after cutting and perforating.

* For low-shrink film as defined in Appendix 2, A shall be 0.628 ± 0.001 and E shall be 0.0355 ± 0.0020 in.

† In any group of four consecutive perforations, the maximum difference of pitch shall not exceed 0.001 in. and should be as much smaller as possible.

‡ This dimension represents the length of any 100 consecutive perforation intervals.

Approved December 17, 1953, by the American Standards Association, Incorporated
Sponsor: Society of Motion Picture and Television Engineers

*Universal Decimal Classification

Printed in U.S.A.
ASA½M154

Price, 25 Cents

(These Appendixes are not a part of American Standard Dimensions for 16mm Film, Perforated Two Edges, PH22.5–1953.)

Appendix 1

The dimensions given in this standard represent the practice of film manufacturers in that the dimensions and tolerances are for film immediately after perforation. The punches and dies themselves are made to tolerances considerably smaller than those given, but owing to the fact that film is a plastic material, the dimensions of the slit and perforated film never agree exactly with the dimensions of the punches and dies. Shrinkage of the film, due to change in moisture content or loss of residual solvents, invariably results in a change in these dimensions during the life of the film. This change is generally uniform throughout the roll.

The uniformity of perforation is one of the most important of the variables affecting steadiness of projection.

Variations in pitch from roll to roll are of little significance compared to variations from one sprocket hole to the next. Actually, it is the maximum variation from one sprocket hole to the next within any small group that is important. This is one of the reasons for the method of specifying uniformity in dimension B.

Appendix 2

In the early days of 16mm film the safety base used for this film had the characteristic of shrinking very rapidly to a certain fairly definite amount and then not shrinking much more. Although this film tended to swell at high humidities, nevertheless the shrinkage that occurred in the package before the user received the film was always at least as great as any swell that might occur due to high humidities at the time of use. This meant that the user never encountered film, even at high humidities, that had greater width than that specified in the standards. This meant that camera and projector manufacturers seldom ran into trouble so long as their film gates would readily pass film at the upper limit of the slitting tolerances, namely 0.630 in.

Within the past few years, however, a safety base with lower shrinkage characteristics began to be used. Although this film was less susceptible than the previous film to swelling at high humidities, nevertheless the shrinkage characteristics were low enough so that this shrinkage did not always compensate for the swell at high humidities.

For this reason film slit at the mid point of the tolerance for width, namely 0.629 in., would occasionally swell at high humidities to such an extent that it would bind in film gates designed to pass film with the width of 0.630 in. The manufacturers, therefore, were compelled to slit at the lower edge of the tolerance permitted by the previous edition of this standard. Variations in their slitting width, however, sometimes produced film slit below the limits of the standard.

This revision has therefore been adopted in order that the manufacturers may slit low-shrink film within the standard and still produce film which does not exceed 0.630 in. even at high humidities.

For the purpose of this specification, low-shrink film base is film base which, when coated with emulsion and any other normal coating treatment, perforated, kept in the manufacturer's sealed container for 6 months, exposed, processed, and stored exposed to air for a period not to exceed 30 days at 65 to 75 F and 50 to 60% relative humidity and measured under like conditions of temperature and humidity, shall have shrunk not more than 0.2% from its original dimension at the time of perforating. The final measurement should be made after conditioning the film for 24 hours to a humidity of 55 ± 5%.

This definition of low-shrink film is to be used as a guide to film manufacturers, and departure therefrom shall not be cause for rejection of the film.

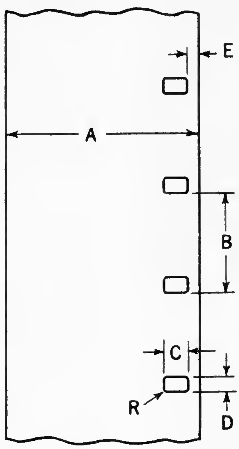
American Standard

Dimensions for 16mm Film, Perforated One Edge

ASA
Reg. U.S. Pat. Off.

PH22.12–1953

Revision of Z22.12–1947
*UDC 778.5



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*E	0.036 ± 0.002	0.91 ± 0.05
‡L	30.00 ± 0.03	762.00 ± 0.76
R	0.010	0.25

These dimensions and tolerances apply to negative and positive raw stock immediately after cutting and perforating.

* For low-shrink film as defined in Appendix 2, A shall be 0.628 ± 0.001 and E shall be 0.0355 ± 0.0020 in.

† In any group of four consecutive perforations, the maximum difference of pitch shall not exceed 0.001 in. and should be as much smaller as possible.

‡ This dimension represents the length of any 100 consecutive perforation intervals.

Approved December 17, 1953, by the American Standards Association, Incorporated
Sponsor: Society of Motion Picture and Television Engineers

*Universal Decimal Classification

Printed in U.S.A.
ASA½M154

Price, 25 Cents

(These Appendixes are not a part of American Standard Dimensions for 16mm Film, Perforated One Edge, PH22.12–1953.)

Appendix 1

The dimensions given in this standard represent the practice of film manufacturers in that the dimensions and tolerances are for film immediately after perforation. The punches and dies themselves are made to tolerances considerably smaller than those given, but owing to the fact that film is a plastic material, the dimensions of the slit and perforated film never agree exactly with the dimensions of the punches and dies. Shrinkage of the film, due to change in moisture content or loss of residual solvents, invariably results in a change in these dimensions during the life of the film. This change is generally uniform throughout the roll.

The uniformity of perforation is one of the most important of the variables affecting steadiness of projection.

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For this reason film slit at the mid point of the tolerance for width, namely 0.629 in., would occasionally swell at high humidities to such an extent that it would bind in film gates designed to pass film with the width of 0.630 in. The manufacturers, therefore, were compelled to slit at the lower edge of the tolerance permitted by the previous edition of this standard. Variations in their slitting width, however, sometimes produced film slit below the limits of the standard.

This revision has therefore been adopted in order that the manufacturers may slit low-shrink film within the standard and still produce film which does not exceed 0.630 in. even at high humidities.

For the purpose of this specification, low-shrink film base is film base which, when coated with emulsion and any other normal coating treatment, perforated, kept in the manufacturer's sealed container for 6 months, exposed, processed, and stored exposed to air for a period not to exceed 30 days at 65 to 75 F and 50 to 60% relative humidity and measured under like conditions of temperature and humidity, shall have shrunk not more than 0.2% from its original dimension at the time of perforating. The final measurement should be made after conditioning the film for 24 hours to a humidity of 55 ± 5%.

This definition of low-shrink film is to be used as a guide to film manufacturers, and departure therefrom shall not be cause for rejection of the film.

PH22.12–1953

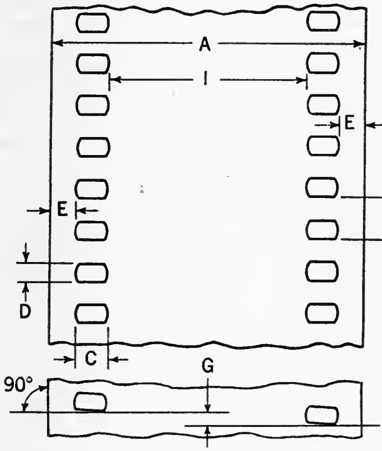
American Standard

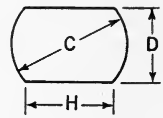
Dimensions for 35mm Motion-Picture Short-Pitch Negative Film

ASA
Reg. U.S. Pat. Off.

PH22.93–1953

*UDC 778.5





Dimensions	Inches	Millimeters
A	1.377 ± 0.001	34.98 ± 0.03
B	0.1866 ± 0.0005	4.740 ± 0.013
C	0.1100 ± 0.0004	2.794 ± 0.01
D	0.073 ± 0.0004	1.85 ± 0.01
E	0.079 ± 0.002	2.01 ± 0.05
G	Not > 0.001	Not > 0.025
*H	0.082	2.08
I	0.999 ± 0.002	25.37 ± 0.05
† L	18.66 ± 0.015	474.00 ± 0.38

These dimensions and tolerances apply to low-shrink negative raw stock immediately after cutting and perforating.

This film is used for motion-picture negatives and certain special processes.

* A calculated value for a dimension not measured routinely in production.

† This dimension represents the length of any 100 consecutive perforation intervals.

This standard is based on American Standard Cutting and Perforating Dimensions for 35-Millimeter Motion Picture Negative Raw Stock, Z22.34–1949 and differs only in the values of B and L and the addition of a second Appendix.

Approved December 17, 1953, by the American Standards Association, Incorporated
Sponsor: Society of Motion Picture and Television Engineers

*Universal Decimal Classification

(These Appendixes are not a part of American Standard Dimensions for 35mm Motion-Picture Short-Pitch Negative Film, PH22.93–1953.)

Appendix 1

The dimensions given in this standard represent the practice of film manufacturers in that the dimensions and tolerances are for film immediately after perforation. The punches and dies themselves are made to tolerances considerably smaller than those given, but owing to the fact that film is a plastic material, the dimensions of the slit and perforated film never agree exactly with the dimensions of the punches and dies. Shrinkage of the film, due to change in moisture content or loss of residual solvents, invariably results in a change in these dimensions during the life of the film. This change is generally uniform throughout the roll.

The uniformity of perforation is one of the most important of the variables affecting steadiness of projection.

Variations in pitch from roll to roll are of little significance compared to variations from one sprocket hole to the next. Actually, it is the maximum variation from one sprocket hole to the next within any small group that is important.

Appendix 2

Most motion–picture film is printed on sprocket-type printers. Maximum steadiness and definition are secured on a sprocket-type printer when the negative film is somewhat shorter in pitch than the positive stock.

For many years, this difference in pitch has come about due to shrinkage of the negative film base on processing and aging.

There are currently becoming available new low-shrink film bases which do not shrink sufficiently to provide the necessary pitch differential between negative and print stock for proper printing on sprocket-type printers. This standard is intended to give dimensions for perforating low-shrink film material so that it will have, as nearly as possible, optimum dimensions at the time of printing.

For the purpose of this specification, low-shrink film base is film base which, when coated with emulsion and any other normal coating treatment, perforated, kept in the manufacturer's sealed container for 6 months, exposed, processed, and stored exposed to air for a period not to exceed 30 days at 65 to 75 F and 50 to 60% relative humidity and measured under like conditions of temperature and humidity, shall have shrunk not more than 0.2% from its original dimension at the time of perforating. The final measurement should be made after conditioning the film for 24 hours to a humidity of 55 $\pm$ 5%.

This definition of low-shrink film is to be used as a guide to film manufacturers, and departure therefrom shall not be cause for rejection of the film.

PH22.93–1953

American Standards for Still Photography

BELOW ARE LISTED the numbers and titles of recently approved American Standards in the field of still photography. Additional listings of such standards will be published in the *Journal* from time to time, as they are made available, as a service to those readers who maintain an active interest in still, as well as motion-picture photography. A previous enumeration of PH3 and PH4 Standards appeared on page 82 of the July 1953 *Journal.*

Photographic Sensitometry, PH2

Sensitometry and Grading of Photographic Papers, PH2.2-1953 (Revision of Z38.2.3-1947)

Exposure Guide Numbers for Photographic Lamps, PH2.4-1953

Photographic Apparatus, PH3

Specifications for Contact Printers, PH3.8-1953 (Revision of Z38.7.10-1944)

Specifications for Masks (Separate) for Use in Photographic Contact Printing of Roll Film Negatives, PH3.9-1953 (Revision of Z38.7.12-1944)

Dimensions for Stereo Still Pictures on 35-Millimeter Film, 5-Perforation Format, PH3.11-1953

Specifications for Attachment Threads for Lens Accessories, PH3.12-1953 (Revision of Z38.4.12-1944)

Dimensions of Front Lens Mounts for Cameras, PH3.14-1944 (Reaffirmation—formerly designated as Z38.4.10-1944)

Specifications for Printing Frames, PH3.15-1944 (Reaffirmation—formerly designated as Z38.7.11-1944)

Method for Determining Resolving Power of Lenses for Projectors for 35-Mm Slidefilm and 2- × 2-Inch Slides, PH3.16-1947 (Reaffirmation—formerly designated as Z38.7.16-1947)

Photographic Processing, PH4

Requirements for Photographic Grade Blotters, PH4.10-1953

Specification for Photographic Grade Ammonium Chloride, (NH_4Cl), PH4.183-1953

Specification for Photographic Grade Ammonium Sulfate, ($(NH_4)_2SO_4$), PH4.184-1953

Correction in the "Single-Copy" Printing of American Standard 16mm Motion Picture Projection Reels, PH22.11–1953

This American Standard as published in the September 1953 *Journal* is correct in its entirety. However, the Standard as published and released by ASA in October 1953 under the box heading "Revision of Z22.11-1941, Z52.33-1945 and PH22.11-1952" shows a typographical error in Table 2, col. 3, on page 2. The "Lateral run-out,[7] maximum" dimension should read "0.057" instead of "0.570." The American Standards Association plans to insert a correction slip with all PH22.11-1953 standards sold in future.

75th Convention and High-Speed Photography

Government and industrial workers are already inquiring about the high-speed photography sessions on the Spring Convention Program, to be held May 3–7 at the Hotel Statler, Washington, D.C. Because government employees often have to apply for travel authorization 90 days in advance, information will be released as soon as it becomes available.

Plans, still tentative but revised since the December *Journal*, now are that the Thursday Afternoon, May 6, session will be a very substantial session on high-speed photography of interest to specialists and the Society's membership in general. It will feature these two basic papers:

"The Photography of Motion" by Morton Sultanoff and John Waddell

"History of the Electronic Flash" by Harry Parker

Two briefer papers on high-speed photography techniques will also be scheduled for this session.

Then, for Friday morning, with the first of two television sessions running concurrently with it, there will be a second high-speed photography session to include papers on techniques and applications and demonstrations.

The Postal Announcement, probably combining for economy's sake the customary folded post card (with hotel rates) and the major aspects of the Advance Program, is scheduled to go out late this month. Program Chairman Joe Aiken and Vice-Chairman John Waddell who is working particularly on the high-speed sessions assure the membership that traveling plans for the high-speed sessions can be made firmly on the above information.

Many papers in addition to those listed in the December *Journal* are now covered by Author Forms. The deadline for Author Forms to reach Chairman Aiken is February 22 — and March 29 for copies of manuscripts and illustrations to reach Society headquarters.

Author Forms are available from any of the Papers Committee listed in the November *Journal*, or from Society headquarters. Author Forms should be submitted early to permit the scheduling of papers.

Central Section Meetings

The Central Section of the SMPTE met at 8:00 p.m. on November 19, 1953, at the Bell & Howell plant, Chicago. Malcolm G. Townsley, P. C. Foote, A. B. Cox and H. H. Brauer discussed photographic and sound techniques in connection with wide-screen processes, and the 16mm and 35mm anamorphic lenses being produced by Bell & Howell were shown. At the conclusion of the talks the members saw some 16mm wide-screen reduction prints from a Marilyn Monroe picture and from *The Robe*, and some 16mm wide-screen originals made by Bell & Howell employees. Approximately 225 persons were in attendance.

On December 10, 1953, the Section met at 8:00 p.m. in the Civic Theatre at Television Station WBKB, 20 N. Wacker Dr., Chicago. James L. Lahey, President of Dage Electronics Corp., Beech Grove, Ind., presented a paper on "The Dage Vidicon Camera and Associated Equipment for Film and Studio Use." At the conclusion of Mr. Lahey's paper a film, *The Living City*, supplied by Encyclopedia Britannica, was shown on the Dage equipment. A matching print was televised at the same time through a closed circuit on WBKB studio equipment. Matching monitors were set up on the stage so that the entire audience could check the visual results. After the film, two cameras, the Vidicon and the studio's standard equipment camera, were used for live pick-ups from the stage.

A Symposium Panel was established under George Ives. The members of the panel answered all questions concerning the new equipment vs. the standard studio equipment and assisted with the demonstration. There were 125 present at the meeting.—*James L. Wassell*, Secretary-Treasurer, Central Section, 247 E. Ontario St., Chicago 11.

Pacific Coast Section Meeting

The October meeting of the Pacific Coast Section of the SMPTE was held on October 20, 1953, at the Twentieth Century-Fox Studios in Beverly Hills. The subject of the evening was "CinemaScope at Twentieth Century-Fox." Due to the unusual interest on the part of our members in this program it was necessary to hold a dual session, one commencing at 7 o'clock, and the other at 8:30. The attendance at each session was limited to 165 persons, and both sessions were filled to capacity.

The meeting featured a presentation of the technical aspects of the CinemaScope process, with specific reference to photography, release printing and exhibition. The group was very appreciative of the concise summary of the CinemaScope engineering features efficiently presented by Lorin Grignon. The program was moderated by Mr. Grignon, and included the following topics:

(1) *The CinemaScope Composite Film.* Mr. Grignon outlined performance requirements and technical considerations leading to the choice of picture, soundtrack and sprocket-hole dimensions, and methods of applying the magnetic soundtracks to the film.

(2) *The CinemaScope Picture.* Joe MacDonald, cameraman for Twentieth Century-Fox, discussed factors pertaining to the photographing, processing and projection of CinemaScope.

(3) *A Sound Printer for CinemaScope.* Ed Templin (Program Chairman of the Pacific Coast Section of SMPTE), of Westrex Corp., described a new multiple-output electrical sound printer for CinemaScope release prints.

(4) *An Exhibition of CinemaScope,* and

(5) *CinemaScope Demonstration.* This gave the members an opportunity to view the process.—*Philip G. Caldwell,* Secretary-Treasurer, Pacific Coast Section, ABC Television Center, Hollywood 27, Calif.

Revised Roster of Atlantic Coast Section Officers

The elected Chairman of the Section, John G. Stott, has departed the environs of New York City to serve the industry in the Color Technology Division, Kodak Park, Eastman Kodak Co., Rochester 4, N.Y., so the roster of Section Officers now at work is:

Everett Miller, Chairman
George H. Gordon, Secretary-Treasurer
George Lewin, Manager
Charles W. Seager, Manager
J. Paul Weiss, Manager
Managers serving their second year are R. C. Holslag, M. H. Searle, R. T. Van Niman.

Book Reviews

The Technique of Film Editing: Basic Principles for TV

Written and compiled by Karel Reisz for the British Film Academy. Published (1953) by Farrar, Straus and Young, 101 Fifth Ave., New York 3, N.Y. 276 pp. + 6 pp. bibliography and glossary + 3 pp. index. Illus. $5\frac{3}{4} \times 8\frac{3}{4}$ in. $7.50.

This is the best book yet available on film editing, either for the layman or for those learning the craft. For some strange reason, in spite of all the books that have been written about film, very few have been about film editing, and even they have mainly consisted of one man's personal and individual approach to the subject. Now for the first time we have a comprehensive book, attempting to make clear "the pivotal contribution of the film editor" to film-making as a whole.

The first quarter of the book is devoted to a short history of editing, showing how the need for it arose, and how it has been affected by the varying requirements of the silent and sound eras.

The main body (and most effective part) of the book goes on to illustrate, with numerous examples, how the elements of editing have been handled by different editors, for quite different purposes. It is thus a book of editing *practice* rather than theory, showing how editing *is* done rather than how it should be done. There are sections on action cutting, dialogue, comedy, "montage," reportage, imaginative documentary, films of ideas, teaching films for the classroom, newsreels and others.

To achieve this, the author has enlisted the expert advice of ten of Britain's top film editors in various fields. Many excellent extracts from finished films illustrate typical points in the text. Each extract includes a shot-by-shot description, the length of each shot, and a sound track breakdown of music, effects, dialogue or commentary, together with still frames from each shot wherever necessary. Only well-known English-language films (from the U.S. and the U.K.) are included, to avoid language problems. Among these are *Birth of a Nation*, *Naked City*, *Topper Returns*, *Citizen Kane*, *Rope*, *Great Expectations*, *Lady from Shanghai*, *Tobacco Road*, *Louisiana Story*, *Night Mail* (about two dozen different films altogether).

The best quarter of the book deals with the "principles of editing," covering such problems as continuity, "smooth" cutting, timing, pace, rhythm, etc. What there is of it is good, so far as it goes. But there is all too little. Even with this book, there is still room for another dealing with this part of the subject, similarly but much more fully.

Finally, there is a short appendix on cutting room procedure, a bibliography and a glossary, explaining the few technical terms used in the text.

The book's subtitle "Basic Principles for TV" is misleading. It does not appear in the original English edition, and seems to have been added to the American edition as an afterthought to capitalize on the popularity of TV. Actually there is hardly a mention of TV in the text, and there is no material whatever dealing with TV situations. This does not, of course, prevent TV directors from profiting strongly from a thorough knowledge of editing. But readers will be disappointed if they look for anything other than *film* editing in this book.

The price ($7.50) is due to the copious illustrations which are part of the book's special value. The language is simple and clear.—*Thomas C. Daly*, National Film Board of Canada, Ottawa, Ontario.

Television

By F. Kerkhof and W. Werner. Published (1952) by Philips' Technical Library, N. V. Philips' Gloeilampenfabrieken, Eindhoven, Holland. Distributed in U.S. and Canada by Elsevier Press, 402 Lovett Blvd., Houston 6, Tex. i—xv + 406 pp. + 10 pp. appendix + 12 pp. literature list + 4 pp. index. 400 illus. Numerous tables. 6 × 9 in. $7.75.

The subtitle of this book is a guide to its contents: "An Introduction to the Physical and Technical Principles of Television, With Comprehensive Descriptions of Various Electrical Circuits."

Messrs. Kerkhof and Werner are principals of the Television Development Laboratory of Philips Industries — Eindhoven (Holland). The book is one of a group of twenty-five known as the "Philips' Technical Library."

The treatment of television receivers has been emphasized; however, engineering principles involved in the art as a whole have been developed and sufficient detail included on transmitting equipment to aver that the book covers essentially the whole field.

The 13 chapters are: General Review; Physical Principles of Electronic Scanning; Pick-up and Picture Tubes; Transmission and Separation of Information; The Excitation and Application of Electrical Relaxation Phenomena; The Time-Base Generator; Generation of Extra-High Tension for the Picture Tube; Wide-Band Amplifiers; The Transmission Line or Feeder; Aerials; Picture Synthesis; Colour Television; and Television Receivers.

Mathematical treatment of engineering level is included whenever required, providing design equations for the practicing engineer. The rationalized system of Giorgi units is used, conversion tables being provided. As the authors state, the mathematics may be omitted without sensible loss by those who wish to be instructed wholly through qualitative physical concepts.

Although this is a Continental book considerable data are included on British and American television. The American system is sufficiently treated to satisfy the needs of most Americans. For those who wish to compare the three systems the book is invaluable.

In the final chapter schematic diagrams for receivers, complete with parts lists, are given for negative modulated transmissions (Continental and American) and for positive modulated transmissions (British); also presented are symptoms and cures for reception difficulties by means of image photographs. Although this information is usually found only in service publications in America it is proper to repeat that this book is an engineering text.

Most of the references in the bibliography are written in the English language, largely from American engineering and scientific journals.—*Harry R. Lubcke*, Reg. Patent Agent, 2443 Creston Way, Hollywood 28, Calif.

Association of Cinema Laboratories

On the day before the opening of the SMPTE Convention in Washington, D.C., in October 1952, Neal Keehn of The Calvin Company invited representatives of several motion-picture laboratories to a dinner party in his suite at the Hotel Statler. The purpose of the dinner and the meeting that followed was, as Mr. Keehn stated, "to give motion-picture laboratory people an opportunity to get to know each other better and to discuss some of their mutual problems." This dinner-meeting was attended by representatives of Byron, Inc.; The Calvin Company; Geo. W. Colburn Laboratory, Inc.; Color Service, Inc.; Du Art Laboratories, Inc.; and McGeary-Smith Laboratories, Inc.

At that meeting it was agreed that free and frank discussion of technical, administrative and managerial problems would be of great benefit to those participating and to the motion-picture laboratory industry as a whole. Later, during the week of the SMPTE Convention, a second meeting was held, hosted by Byron Roudabush of Byron, Inc., at which the advantages and disadvantages of forming a formal motion-picture laboratory association were discussed. It was agreed that another meeting should be held, preferably in New York City, at which a considerably larger representation of laboratories would be possible so that a wider base of opinion could be sounded out.

This third meeting, with Du Art Film Laboratories, Inc., as host, could be called the first organizational meeting. Representatives of 16 motion-picture laboratories attended this meeting, and it was voted that a formal trade association would be formed. Plans were formulated to incorporate the association under the laws of the State of New York. Interim officers were elected: John G. Stott, President; Russell Holslag, Treasurer; and Harry B. Sale, Secretary. Annual dues of $50.00 were voted and a tentative program of activity was worked out.

It was hoped that the name of the association could be "The Association of Motion Picture Laboratories, Inc." However, it was learned that a previous association formed years ago had obtained this name and had never been legally dissolved. Hence the name was not available. The officers of the embryo association settled, then, on the present name: "The Association of Cinema Laboratories, Inc." as the next best thing. The association obtained its charter under the laws of the State of New York in March 1953, and a list of bylaws was drawn up.

Subsequent meetings were concerned primarily with organizational details such as approval of the bylaws, appointment of Membership, Admissions, Technical and Executive Committees, and determination of financial, administrative and publicity policies.

At a meeting of the Board of Directors held in July 1953, the first permanent officers of the Association were elected and installed. These officers are:

Neal Keehn . . . . . President
John G. Stott . . . . Vice-President
Byron Roudabush . . Secretary
Geo. W. Colburn . . Treasurer

The first general meeting of the association under its permanent officers was held November 13, 1953, in Chicago.

The purpose of the Association of Cinema Laboratories, Inc., is to provide a clearinghouse and area for debate on various technical and business problems common to all motion-picture laboratories. Some of the typical problems presently being worked on are as follows:

(1) Recommendations for preparation of A and B rolls for 16mm printing.

(2) Recommendations for use of standard head and tail leaders for 16mm printing.

(3) Elimination of notches on 16mm printing films and substitution of an electrical edge-cuing technique.

(4) Preparation of a uniform terminology, nomenclature, list of parts, equipment, films, devices and techniques.

(5) Investigation of means of securing screen credits for processing and printing laboratories.

(6) Establishment of a bureau for the voluntary exchange of technical information.

(7) Providing means of encouraging research on motion-picture laboratory technical problems and of providing a flow of specially trained engineering personnel into the motion-picture laboratory industry by a system of scholarships or fellowships to universities or colleges.

The above items are only those on which positive activity is now in progress. Many other matters are under discussion.

It must be emphasized that the Association of Cinema Laboratories, Inc., does not compete with purely technical societies but tends instead to supplement and implement the activities of those societies. Technical recommendations or standards set up, say by the SMPTE, may be more readily adopted through the devices of the Association of Cinema Laboratories, Inc. Our activities also embrace matters beyond the province of purely technical societies.

One of the greatest benefits of the Association is the opportunity it provides for personal contact between competitors in an atmosphere of friendly and open debate. The Association, chartered under expert legal supervision, forbids discussions of prices or pricing methods. Free interchange of information has brought out that facilities exist in one laboratory that do not exist in another, making it possible to "farm out" jobs with the knowledge that the laboratory to which the job is "farmed" is adequate for the task.

Thus has been our birth and growth in just a little over a year. We're proud that we already have 26 paid-up members. The formation of such an association has been a great task. Plagued by inexperience in such matters, separated as individual laboratories by great distances, struggling with differing problems, methods, needs, requirements and resources, we have our hands full. Our problem now is to communicate effectively with those members who have not so far benefited by attending the 1953 meetings. Our progress probably will be slow, and we'll need all the help we can get. But the rewards are great and we look forward with enthusiasm and confidence to expanding membership and activity.—*John G. Stott*, Vice-President, The Association of Cinema Laboratories, Inc., 1226 Wisconsin Ave., Washington, D.C.

New Members

The following members have been added to the Society's rolls since those last published. The designations of grades are the same as those used in the 1952 Membership Directory.

Honorary (H) Fellow (F) Active (M) Associate (A) Student (S)

Boyle, Charles P., Cameraman, Director of Photography, Universal Studios. **Mail:** 12628 Otsego St., North Hollywood, Calif. (M)

Carlson, Kenneth, Television Film Producer, Larchmont Studios. **Mail:** 1212 North Normandie, Hollywood 29, Calif. (A)

Cramer, Mert, Student, University of California at Los Angeles. **Mail:** 2341 Hillhurst Ave., Los Angeles 27, Calif. (A)

Dolotta, T. A., Drinker 104, Lehigh University, Bethlehem, Pa. (S)

Dowson, Philip Hugh Bourne, Company Director and Chief Engineer, H. A. O'Connor & Co., Ltd., Laidlaw Building, P.O. Box 252, Singapore, Malaya. (A)

Eaton, Richard Edwin, Physicist, U.S. Government — WPAFB. **Mail:** 5693 Gross Dr., Dayton, Ohio. (M)

Edwards, Thomas A., Designer, Engineering and Manufacturing. **Mail:** 10213 Pescadero Ave., South Gate, Calif. (M)

Fleming, Malcolm L., Indiana University. **Mail:** Hoosier Courts 23–7, Bloomington, Ind. (S)

Fournier, Rudolphe, TV Technical Maintenance Supervisor, Canadian Broadcasting Corp. **Mail:** 826 Riverview Ave., Verdun, Quebec, Canada. (A)

Foxe, Morton, Staff Engineer, General Precision Laboratories. **Mail:** 796 Bronx River Rd., Bronxville, N.Y. (A)

Garver, Ray, Chief Engineer, in charge of design, Garver Electric Co. **Mail:** 617 North Columbia St., Union City, Ind. (A)

Gerrie, Alfred L., Jr., California State Polytechnic College. **Mail:** 1118 North El Molino Ave., Pasadena 6, Calif. (S)

Gerstner, John E., U.S.A.F. Quality Control Representative, U.S. Air Force. **Mail:** 86–27 — 85 St., Woodhaven 21, N.Y. (A)

Gottling, James G., Lehigh University. **Mail:** 458 Center St., Bethlehem, Pa. (S)

Gross, C. Robert, Engineer, Columbia Broadcasting System. **Mail:** 8439 Tunney Ave., Northridge, Calif. (A)

Hinerman, Millard T., Motion-Picture Printing and Processing-Equipment Mechanic, U.S. Naval Photographic Center. **Mail:** 3339 Buchanan St., #301, Mt. Rainier, Md. (A)

Huot, Louis, Producer, Huot Productions, Inc. **Mail:** 2875 Glendale Blvd., Los Angeles 39, Calif. (M)

Killian, Kenneth K., Manufacturer's Representative. **Mail:** Box 364, Hempstead, N.Y. (A)

Laidlaw, Ron, Film and Photographic Director, CFPL-TV, London Free Press Printing Co., Ltd., Richmond St., London, Ontario, Canada. (A)

Lambert, Sam, Unit Manager and Assistant Director, Magna Theatre Corp. **Mail:** 200 W. 54 St., New York, N.Y. (A)

Leslie, Edward S., Model Maker, RCA Victor Div., Radio Corporation of America, 1560 North Vine, Hollywood, Calif. (A)

Luce, Ralph W., Motion-Picture Producer, Pearson & Luce Productions, 505 Geary St., San Francisco, Calif. (M)

Martinez, Rene C., Illuminating Consultant, Otto K. Olesen Illuminating Co. **Mail:** 9012 Crescent Dr., Hollywood 46, Calif. (M)

McCubbin, John G., Mechanical Engineer, RCA Victor Div., Radio Corporation of America. **Mail:** 2912 Washington St., Camden 5, N.J. (A)

McDonald, Duncan Hamilton, Branch Manager, General Theatre Supply Co. **Mail:** 266 Waterloo St., St. John, N.B., Canada. (A)

McGreal, E. B., Head, Film Operations, Young & Rubicam. **Mail:** 8423 Fountain Ave., Los Angeles 46, Calif. (A)

McNamara, Daniel N., Television Engineer, Columbia Broadcasting System. **Mail:** 17353 Hatteros St., Encino, Calif. (A)

Milner, Irving, Chief Projectionist, Skouras Theatres Corp. **Mail:** 221–12 — 69 Ave., Bayside 64, N.Y. (M)

More, Harry, Manager, Westrex Co. (Asia), 304 Victory House, Hong Kong. (M)

Mueller, George J., Engineer-Physicist Consultant, Douglas Aircraft Co. **Mail:** 456 North Bowling Green Way, Los Angeles 49, Calif. (M)

Newman, James J., Executive Head, Coast Film Service. **Mail:** 3611–31st St., San Diego 4, Calif. (M)

Palmieri, Victor A., Television Engineer, KLAC-TV. **Mail:** 521 La Paz Dr., Pasadena 10, Calif. (A)

Parrish, Fred A., Motion-Picture Cameraman. **Mail:** 10851 Fairbanks Way, Culver City, Calif. (A)

Phillips, Alex, Motion-Picture Cameraman, Heriberto Frias, 948 Col. del Valleiz, Mexico, D.F. (A)

Picker, Eugene, Theatre Executive, Loew's, Inc., 1540 Broadway, New York, N.Y. (A)

Plambech, Albert O., President and Technical Director, Horn Jefferys & Co. **Mail:** 4757 Anola Ave., North Hollywood, Calif. (M)

Randolph, Dorthia, Research Technician, Melpar, Inc. **Mail:** 5662 Eighth Rd., North, Arlington, Va. (A)

Rankin, John A., Vice-President, Director of Engineering, The Magnavox Co., Fort Wayne 4, Ind. (M)

Raskin, L. J., TV Engineer, Kinescope Recording, National Broadcasting Co. **Mail:** 11016 Califa St., North Hollywood, Calif. (A)

Rippe, Herbert Louis, Assistant Project Engineer, U.S. Government — WPAFB. **Mail:** Thomas Trailer Court, Fairborn, Ohio. (M)

Rosenthal, Murray, Cameraman and Service. **Mail:** 2601 Tenth Ave., South, Birmingham, Ala. (A)

Row Kavi, Sadashiv J., Motion-Picture Producer and Distributor, Chitra Sahakar (Production Unit), 2 C & D, "Naaz," Lamington Rd., Bombay 4, India. (M)

Schaefer, Fred J., Sound and Projection Engineer, European Motion-Picture Service, U.S. Army. **Mail:** Robinson Barracks Apts., 6B-3, Stuttgart, Bad Canstatt, Germany. (M)

Shono, Nobuo, Chief Engineer, Fuji Photo Film Co., Minamiashigaracho, Kanagawaken, Japan. (A)

Solomon, Robert, Industrial Engineer, U.S. Naval Supply Research & Development Facility. **Mail:** 200 E. 16 St., New York 3, N.Y. (A)

Stark, Milton, Motion-Picture Producer, Stark-Films, 537 North Howard St., Baltimore 1, Md. (M)

Stensvold, O. C. Alan, Cinematographer. **Mail:** 3724 Muirfield Rd., Los Angeles 16, Calif. (M)

Thomas, Dolph, Business Representative, International Sound Technicians, Local 695, 7614 Sunset Blvd., Hollywood 46, Calif. (M)

Thomas, Donn H., Public Relations Director, Pacific Union Conference of Seventh-Day Adventists, 1545 North Verdugo Rd., Glendale, Calif. (M)

Thomas, William H., Executive, James B. Lansing Sound, Inc., 2439 Fletcher Dr., Los Angeles 39, Calif. (M)

Vandervort, D. L., Physicist, Eastman Kodak Co., Kodak Park, Rochester, N.Y. (A)

Walker, A. Prose, Manager of Engineering, National Association of Radio & Television Broadcasters, 1771 N St., N.W., Washington 6, D.C. (M)

Warren, Aubrey C., Manufacturer, 10633 Chandler Blvd., North Hollywood, Calif. (M)

Weller, William R., Photographic Engineer, Eastman Kodak Co. **Mail:** 381 Meadow Dr., Rochester 18, N.Y. (A)

Williams, Howdy L., Cameraman. **Mail:** 8021 Radford Ave., North Hollywood, Calif. (M)

DECEASED

Weisser, Frank E., President, Color Laboratories, Inc., P.O. Box 637, Islip, N.Y. (M)

New Products

Further information about these items can be obtained direct from the addresses given. As in the case of technical papers, the Society is not responsible for manufacturers' statements, and publication of these items does not constitute endorsement of the products.

A new 300-w intensity light source has been offered by Bell & Howell, to produce up to 215 ft-c at the printing aperture. In addition to the greatly increased light output, the new unit has improved uniformity in density across the printing aperture, a dowser shutter permitting preheating to desired color temperature, a new design for cooling the lamp and filters, new heat-absorbing glass, a printing lamp with a 200-hr life, a suppressed scale-type ammeter and a rheostat for greater exposure range. The price is $595.

Involving no major physical changes in existing equipment, this unit will be available as standard equipment on all new 16mm and 35mm Bell & Howell printers manufactured after the first of this year. Installation of the unit on printers now in the field can be readily accomplished without returning the printer to the factory.

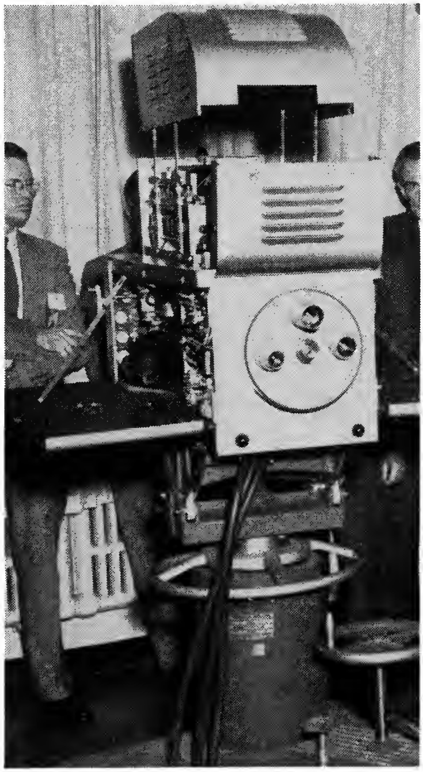
Design uses a 300-w, 120-v base-up lamp with a 200-hr life. The light intensity is controlled by a 35-ohm rheostat from 1.8 to 2.66 amp shown on the ammeter of the suppressed-scale type which makes possible a closer reading of light intensity. A small additional reflector alongside the main spherical filament reflector furnishes light for the edge printing.

Automatic cooling is provided for the lamp, filters and rheostat. The gelatin color filters are further protected by a heat-absorbing glass filter. By a special switching arrangement, the cooling fan will continue to operate after the lamp is shut off, thus preventing a heat build-up at the gelatin filters.

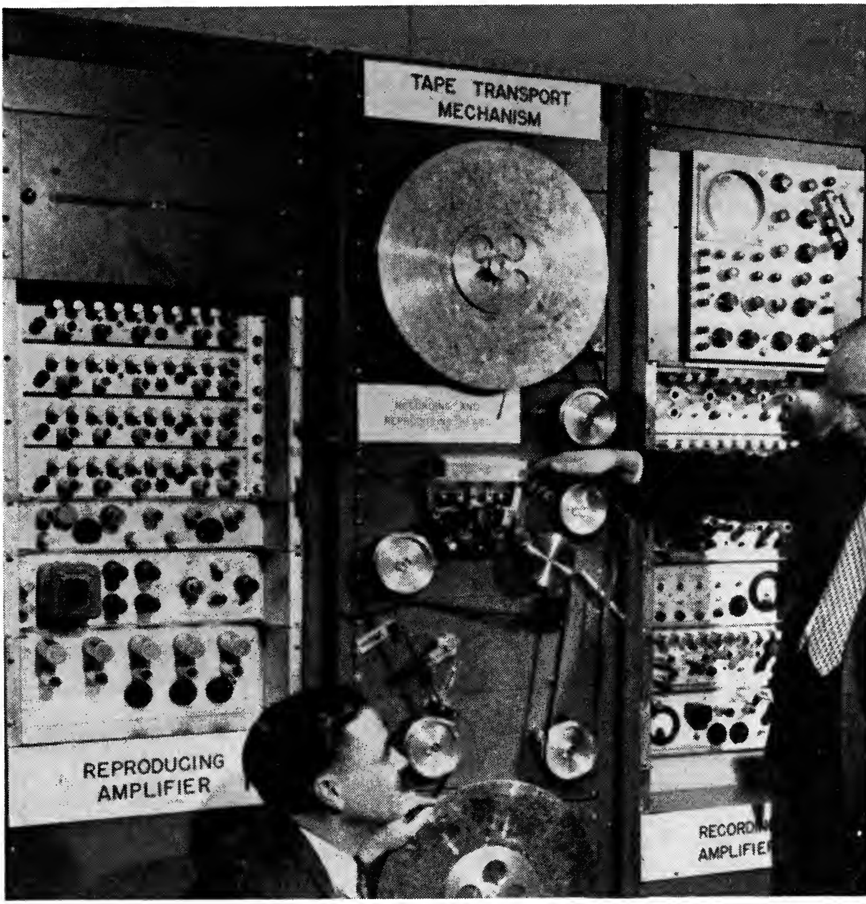
The optical system has one cylindrical and two spherical condensers. A prism is used to bend the rays. The coated optical elements increase the light intensity to more than 10 times over the nonoptical attachment. The addition of a cylindrical condenser elongates the light spot at the aperture, giving uniform light intensity across the aperature for both 16mm and 35mm film sizes.

A ring-type spacer is used on top of the lamphouse for aligning the prism and second condenser. Realigning is not required after the original adjustment is made. Two screws tighten the ring to the lamphouse.

For normal exposure at 60 fpm using Eastman fine-grain, release positive film with a 1.5 neutral density filter, the ammeter reading is set to 1.8 amp and the shutter to stop # 8. The exposure for color printing will depend on the color filters used, in addition to lamp current and shutter stop. For checking exposure correctly, a densichron meter with a special Bell & Howell attachment should be used. The range in foot-candles without neutral density filter is 35 to 415 with # 22 stop.



RCA's new Color TV Camera was demonstrated in October at Camden to a clinic of broadcast consulting engineers. RCA has announced that it will start delivering color telecasting equipment before the end of 1953. The first equipment, consisting of color monitors and terminal apparatus to be added to existing television transmission facilities, is designed to enable stations to telecast programs received over telephone circuits. Other equipment is planned for next year for transmitting in color from slides, film and live studio productions. The equipment now being produced is on a custom basis, for the standards approved by the FCC may be such that some modification will be required in commercial production to come later.

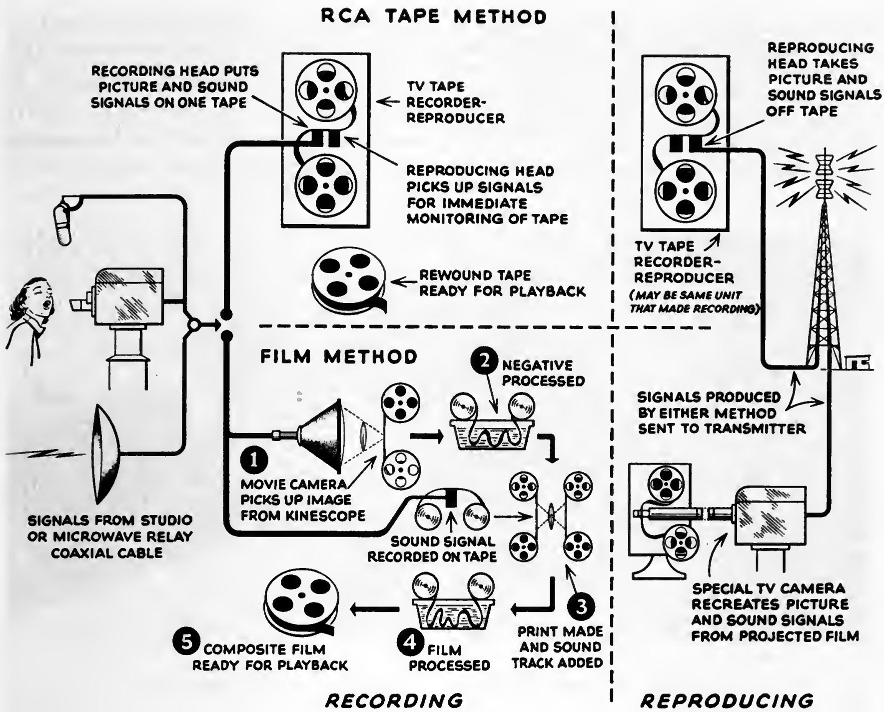


Video recording on magnetic tape was demonstrated for the first time by RCA on December 1, 1953. A color television program originating in NBC studios in Radio City, New York, was beamed by microwave to the David Sarnoff Research Center at Princeton, N.J., and there simultaneously shown and recorded on magnetic tape. During part of this transmission, both the live program from the microwave radio relay and an immediate playback of the magnetic tape recording were shown on two separate receivers. As soon as the tape reel was rewound, it was played back and the recorded television pictures appeared on the two color television receivers. Black-and-white reproduction was also demonstrated.

The principle of video recording resembles that of sound recording. Since video signal frequencies range up to 4 mc, however, special recording and reproducing heads had to be developed in order to bring tape speed within manageable limits. In the equipment demonstrated tape speed was 30 fps, and recording was said to reach 3 mc.

Reels used with the demonstration equipment were 17-in., capable of recording 4 min of a television program. RCA is working now for a 19-in. reel which will carry a 15-min program.

Special recording and reproducing amplifiers have been designed to take into account and compensate for the characteristics of the heads and magnetic tape ma-



terials in recording the wide bands of frequencies used in television.

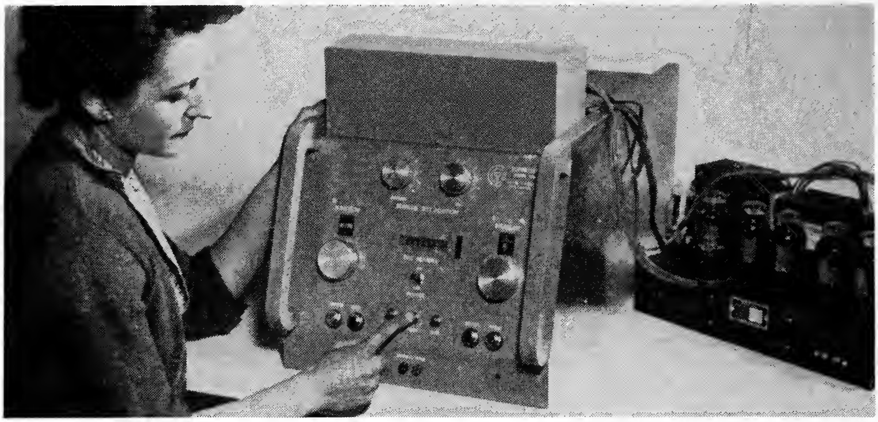
Since even small variations in the speed of the tape and the pressure on the head can create noticeable effects on the picture, it was necessary to devise precision apparatus to control accurately the speed of the tape at the recording and reproducing points. Greater precision in regulating speed and pressure is the object of research which RCA has under way.

For video tape recording of color television with the RCA system, five parallel channels are recorded on ½-in. tape. There is one recorded channel for each of the primary color signals (red, green and blue), for the synchronizing signal, and for the sound signal. For black-and-white recording the ¼-in. tape carries two recorded channels, one to carry the video signal and the synchronizing signal, and one for the sound signal.

To rebroadcast a color television program from a tape recording it would be necessary to combine the three primary color signals with the synchronizing signal to form a composite signal to send to the transmitter. While this operation is not yet ready for demonstration, RCA says that it is the subject of current development.

RCA has released comparative estimates of operating costs which are highly favorable to tape as opposed to film recording. Although magnetic tape today costs more per minute of program time than 35mm color film, the fact that tape needs no processing before playback compensates for the expense of raw tape. Recording black-and-white programs on film is estimated by RCA engineers to be at least five times as costly as it would be on ¼-in. magnetic tape, assuming that the tape would be reused many times. In making copies for distribution to television stations, they say, a half-hour program could be taped for less than $15 per copy, provided the tape is reused. Even greater economies are estimated for making the original tape recording of color television programs, which under normal operating circumstances could be handled for only 5% of the cost entailed in color film recording. In making copies on tape that is to be reused, a tape recording of a half-hour color program would cost roughly $20.

Despite the very visible line structure and the slight washout of color, viewers at the demonstration appeared to be agreeably impressed with the accomplishments in developing this new technique. RCA's estimate is that equipment will be available commercially in about two years.



The new CTI Supertester, manufactured by Color Television Inc., 994 San Carlos Ave., San Carlos, Calif., permits testing of electronic or electrical products at the rate of several checks per second. As many as 400 individual automatic sequenced tests can be made.

The tests themselves can be distributed as required among the following six basic types: continuity, leakage, d-c voltage, a-c voltage, resistance and impedance. In addition, derivative characteristics such as gain, frequency response, phase relationships and noise levels are determined automatically through the combination of two or more of the standard tests. Circuitry is included to allow manual dialing to any one of the tests. Accessory signal generators, dropping resistors, etc., can be used with this tester to permit tests at frequencies or voltages outside its normal scope.

The master cabinet contains the basic switching units and electronic measuring circuits. No internal changes or adjustments are required for any test sequence. Adapters, which are plugged into the top of the master cabinet, are individually laid out and wired to meet the requirements of each particular type of production equipment under test.

In operation, the attendant attaches the adapter leads to the equipment to be tested and presses the starter button. The instrument proceeds through the sequence of tests, sounding an alarm on the discovery of a fault, on reaching a test which requires an adjustment to the product, and on reaching the end of the entire sequence. The adjustment step can be made on a go/no-go basis with the attendant not being required to measure or even understand the particular adjustment.

A new version of the Photovolt Densitometer, including new accessories, is announced in a new bulletin by Photovolt Corp., 95 Madison Ave., New York 16, N. Y. Following indications by R. C. Lovick of Eastman Kodak Co. in his paper "Densitometry of Silver-Sulfide Sound Tracks," published in the August 1952 *Journal*, a special search head is now supplied which permits measurement of infrared density of silver-sulfide sound tracks. The head contains a phototube with S-1 response.

The Neuscope splicer, specially developed for use with CinemaScope film, has been announced by Neumade Products Corp., 330 W. 42 St., New York 36. Although the new splicer resembles the conventional Griswold splicer in appearance it has the smaller-sized pins, differently located, necessitated by the smaller sprocket holes of CinemaScope film.

It has also been found that the way to get a perfect splice in true alignment was by keeping the film locked in one position throughout the splicing operation. Splicing procedure on CinemaScope film has until now meant removing the film from the jaws in the middle of the splice, turning it over, scraping the soundtracks from the back and replacing it in its original position before applying the cement. The Neuscope splicer enables the user to scrape the emulsion from the top of the film in the conventional manner and then remove the soundtracks from the back of the overlap without taking the film out and turning it over — it is locked in its original position throughout the entire splicing operation.

Employment Service

These notices are published for the service of the membership and the field. They are inserted for three months, at no charge to the member. The Society's address cannot be used for replies.

Positions Wanted

Motion-Picture Television Technician: 10 yr intensive skill and know-how related to 16-35mm cinematography, animation, recording (optical, tape, disk), editing, laboratory processing practice (black-and-white, color); also kinescope recording techniques; self-reliant; inventive; relocate if required; write: CMC, Technical Associates, 60 East 42d St., New York 17, N.Y.

Motion-Picture Cameraman: Retiring from Naval Service. 15 yr experience in camera operation, printing, processing, adm. and supervision of production crews. Desires position in TV, educational or industrial field, inaugurating a motion-picture program. Available after May 1954. Prefer West Coast. Write: W. W. Collier, 422 W. Jackson Ave., Warrington, Fla.

Positions Available

Wanted: Sound Engineer for New York film production studio, operation and maintenance on optical and magnetic sound equipment; electronics background essential. Send résumé to R. Sherman, 858 West End Ave., New York, N.Y.

Technical Photographer, age 27 to 38, for senior position with large California industrial research organization. Should be conversant with contemporary techniques for recording data; acquainted with microscopy, graphic arts and color processes. Job involves application of photographic techniques as experimental tool in research projects. Administrative experience helpful. Excellent career opportunity for an ingenious and inventive person. Retirement pension and other benefit plans. Application held in strict confidence. Write giving personal data, education and experience to Henry Helbig and Associates, Placement Consultants, Examiner Bldg., 3d and Market Sts., San Francisco 3, Calif.

Sound Engineer: Complete responsibility for sound control, including printing, processing, maintenance of standards, etc. Tri Art Color Corp., 245 West 55th St., New York 19, N.Y.

Motion-Picture Supervisor, GS-8: Duties as Chief of Motion Picture Section to include all phases of aeromedical research cinematography. Experience in planning, directing, lighting, color control, recording in single or double-system sound. Laboratory work requires experience with sensitometric control equipment, contact printers, automatic processors, Moviola, sound synchronization equipment, titlers, etc. For detailed information write: Photography Officer, USAF School of Aviation Medicine, Randolph Field, Texas.

Motion-Picture Sound Transmission Installer and Repairer, for the Signal Corps Pictorial Center, Long Island City, N.Y.—one at $2.59/hr; one at $2.29/hr (40-hr week). Applicants for $2.29/hr position must have had $4\frac{1}{2}$ yr progressively responsible experience in the construction, installation and maintenance of electronic equipment, of which at least $1\frac{1}{2}$ yr must have been in the specialized field of motion-picture film, disk or magnetic sound recording or reproducing equipment. Applicants for $2.59/hr position must have had at least 5 yr responsible experience in the design, development and installation of electronic equipment, of which at least 2 yr must have been in the specialized field of motion-picture film, disk or magnetic sound recording or reproducing equipment. Must be familiar with filter design and transmission testing, involving the use of a wide variety of testing and measuring devices. Each year of study successfully completed in a residence school above high school level in electrical, electronic or radio engineering, may be substituted for the general, but not the specialized experience indicated above, at the rate of one scholastic year for each 9 mo. of experience. All applicants must be familiar with Western Electric and RCA systems. Obtain Form SF 57 at any first class Post Office or Government Agency; forward or bring completed form to Civilian Personnel Division, Signal Corps Pictorial Center, 35-11 35th Ave., Long Island City, N.Y.

Photographic Engineer: Wanted for design and development work involving application of film and associated equipment to monochrome and color TV systems. Prerequisites are BS or equivalent, and experience in at least one of the following motion-picture fields: (a) TV film applications, (b) processing laboratory design and operation, (c) camera and projector design or (d) sensitometry and densitometry. Please send résumé to Personnel Dept., CBS Television, 485 Madison Ave., New York 22, N.Y.

Sales Management Engineer: To head division manufacturing single optical track stereo sound system. Already adopted by major studio. Position requires knowledge of theater sound systems here and abroad. Reply to: Fairchild, Rm. 4628, 30 Rockefeller Plaza, New York 20, N.Y.

Engineer: To direct engineering of flying-spot TV projector with millisecond pulldown mechanism. Mechanism already developed and working. Reply to: Fairchild, Rm. 4628, 30 Rockefeller Plaza, New York 20, N.Y.

Wanted — Consultant technician: Thorough knowledge of Houston continuous double-head printer, Houston developing machines, Bell & Howell printers and Debrie Matipo step printer. Must put machines in running order and train operating personnel. Usual per day rate and plane fare to Puerto Rico. Address replies to R. J. Faust, Chief, Cinema Section, Dept. of Education, Commonwealth of Puerto Rico, Division of Community Education, P. O. Box 432, San Juan, Puerto Rico.

Meetings

American Institute of Electrical Engineers, Winter General Meeting, Jan. 18-22, 1954, New York

National Electrical Manufacturers Assn., Mar. 8-11, 1954, Edgewater Beach Hotel, Chicago, Ill.

Radio Engineering Show and I.R.E. National Convention, Mar. 22-25, 1954, Hotel Waldorf Astoria, New York

Optical Society of America, Mar. 25-27, 1954, New York

The Calvin Eighth Annual Workshop, Apr. 12-14, 1954, The Calvin Co., Kansas City, Mo.

Society of Motion Picture and Television Engineers, Central Section, Spring Meeting, Apr. 15, 1954, The Calvin Co. Sound Stage, Kansas City, Mo.

75th Semiannual Convention of the SMPTE, May 3-7, 1954, Hotel Statler, Washington

American Institute of Electrical Engineers, Summer General Meeting, June 21-25, 1954, Los Angeles, Calif.

Acoustical Society of America, June 22-26, 1954, Hotel Statler, New York

Illuminating Engineering Society, National Technical Conference, Sept. 12-16, 1954, Chalfonte-Haddon Hall, Atlantic City, N.J.

Photographic Society of America, Annual Meeting, Oct. 5-9, 1954, Drake Hotel, Chicago, Ill.

American Institute of Electrical Engineers, Fall General Meeting, Oct. 11-15, 1954, Chicago, Ill.

76th Semiannual Convention of the SMPTE, Oct. 18-22, 1954 (next year), Ambassador Hotel, Los Angeles

77th Semiannual Convention of the SMPTE, Apr. 17-22, 1955, Drake Hotel, Chicago

78th Semiannual Convention of the SMPTE, Oct. 3-7, 1955, Lake Placid Club, Essex County, N.Y.

SMPTE Officers and Committees: The roster of Society Officers and the Committee Chairmen and Members were published in the April *Journal*.

Growth and Decay of Light Measured Photographically From Flash-Discharge Tubes

By W. R. STAMP and R. P. COGHLAN

A method is described of plotting the light-time curves of flash-discharge tubes using purely photographic methods. Particular attention is given to tubes with flashes of the order of 5- to 10-μsec effective duration, but some results for longer duration tubes are included. The method has been employed to examine for a certain tube the influence on the effective photographic duration of the use of emulsions of widely different spectral sensitivity and speed. For the particular emulsions chosen the observed differences in effective flash duration are of small magnitude and insignificant in practice. Some observations are included of the influence of different capacities on total photographically effective light output (i.e. efficiency). The changes in duration and efficiency resulting from some different gas fillings in tubes which are otherwise identical are also recorded.

THE INCREASING USE of flash-discharge tubes as a light source for photography in almost every branch of research has led to a need for some knowledge of the shape and duration of the light-time curve of these tubes, particularly of the types having a very short flash of the order of microseconds.

Reports of previous work in which these tubes were used for various purposes have frequently included a statement of the effective duration of the flash without describing the means by which the figures were obtained. These were probably based upon the positional accuracy of measurement in the photograph of an object moving at known speed. This criterion has very little reference to the actual total time for which the light is emitted, which is a factor of major importance in other types of investigation.

It became clear, therefore, that it was necessary to devise a method for plotting the complete light-time curve, from which it might be possible, knowing the type of subject to be photographed, to deduce a figure for the effective time of flash in any given case, and thus to estimate in advance the type of lamp and conditions of discharge suitable for any proposed application. In addition, the ability to plot the light-time curve would enable investigations to be made of the effects of various modifications to the lamps, circuitry, or photographic technique, which might result in a reduction of the effective flash time.

Presented on October 9, 1952, at the Society's Convention at Washington, D.C., by W. R. Stamp and R. P. Coghlan, Royal Naval Scientific Service, Admiralty, London, England.
(This paper was received Oct. 15, 1952.)

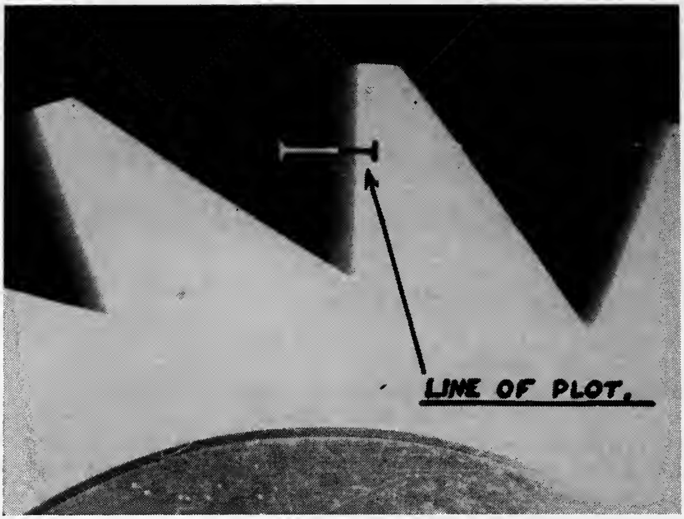


Fig. 1. Typical disk picture.

The Method

Previous work on this problem using a photocell/cathode-ray oscilloscope combination has been devoted to the longer duration discharges of the order of 10^{-4} sec. Even for these durations, this method is open to objection on the grounds that the spectral, and possibly even the time, response of a photocell is like to be totally different from those of photographic emulsions. Corrections cannot be applied, since the spectral quality of the light emitted probably varies during the period of the flash and the determination of such variations would be an extremely difficult task.

It was decided, therefore, that an extension of these methods to flashes of shorter duration was undesirable and that the use of a purely photographic technique would constitute the best procedure, since the question at issue is how photographic emulsions respond to flashtubes, and not how cathode ray oscilloscope/photocell combinations respond to them.

The most direct method of obtaining the required information would be to produce an image of a narrow slit, illuminated by the flash, moving rapidly across the surface of the photographic emulsion in a direction perpendicular to its length. The density profile of the resultant blur in the developed image could then be measured with a microdensitometer, and an evaluation of the light-time curve obtained by reference to the sensitometric curve of the emulsion exposed and developed under the same conditions.

Although possessing the merit of simplicity in principle, the practical achievement of a line image having a satisfactory ratio of width to speed of motion is somewhat difficult.

For this reason, the method actually adopted was that of photographing a rapidly moving edge, or boundary. This has an advantage inasmuch as it closely approaches the conditions found in many applications of flashtube photography. The sharpness of the edge, and hence the "time-resolution" for a given speed, is better than that of any practicable slit. It leads, however, to complications in the computation of

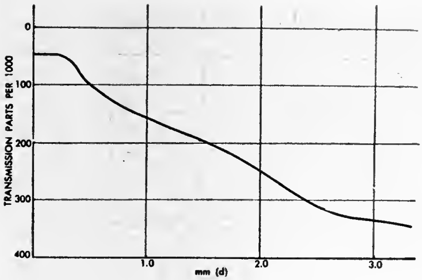


Figure 2

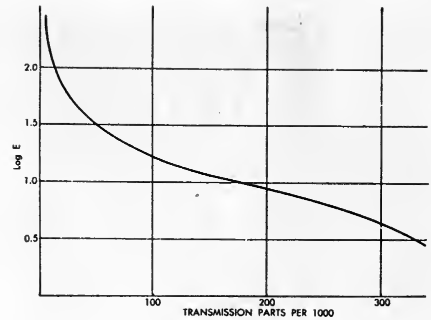


Figure 3

the final curve which add considerably to the labor involved, as will be seen.

The photography of the rapidly moving edge or boundary was performed in two alternative ways. In the first way, which was used in the initial stages of the work, a photograph was obtained with an ordinary camera of a rapidly rotating white disk having a number of slots or teeth cut out around its periphery. This disk was placed against a dead black background and illuminated by the light from a single flash of the flash-tube under examination. The type of photograph which resulted is shown in Fig. 1 in which the rapidly moving boundary between the black and white areas appears as a blur. In the second way, which was used at a later stage to simplify the operation of the apparatus, no camera was used at all, but a length of film was simply mounted as close as possible behind the spinning disk so that a shadow of the disk was cast on it by the light, again from a single flash of the tube. To ensure that this shadow was as sharp as possible the light from the tube was passed through a small aperture before it became incident on the disk and film. The shadowgraph which resulted was similar in appearance to Fig. 1 except that the blacks appeared white and vice versa. It may be mentioned here that the shadowgraph method tended to produce slightly shorter rise times in the final light-time curve than the camera method, which indicates a slightly higher time resolution.

Simultaneously with the production of each photograph or shadowgraph, a strip of the same batch of film was exposed in a tube sensitometer to light from the same flash after reflection from a matte white screen. The photograph or shadowgraph, together with its associated sensitometric strip, were then developed simultaneously, using developers and times of development which would be used in practice for flashtube photographs. By means of a microdensitometer the density (or transmission) profile of the blur in the disk picture along the line shown in Fig. 1 was plotted. The densities on the sensitometric strip were also measured with the same instrument.

The light-time curve of the flash was then derived as follows: From the experimental procedure described two curves were obtained.

(a) A plot of transmission T against distance d along the blur measured circumferentially in the disk picture.

(b) A sensitometric curve of transmission T against Relative Log Exposure.

The form of these curves obtained in a typical case is shown in Figs. 2 and 3.

Both the ordinates and abscissas of Fig. 2 are now transformed:

(c) Distance d is transformed to a time scale t by a linear relationship established from the measured speed of the disk and, in the cases in which the camera was used, the camera image reduction ratio.

(d) Transmission T is transformed to

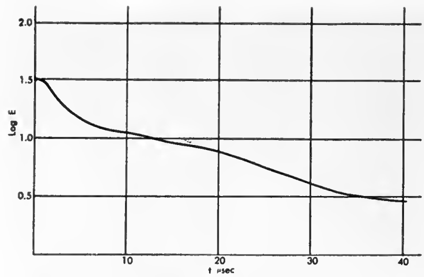


Figure 4

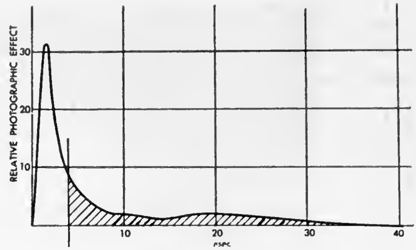


Figure 5

Relative Log E with the aid of the sensitometric curve.

The curve arrived at by applying these processes is shown in Fig. 4.

It is shown below that by differentiating this curve with respect to time, and then plotting the product of the slope and the corresponding exposure at any point against the corresponding time value, the final curve is obtained.

In Fig. 5, which represents the final curve, the line marked t corresponds to the position of the edge at the time t with white on the left and black on the right (since time and distance bear a linear relationship, the abscissas on this graph can be either, interchangeably). It is apparent that the density at this particular point on the blur will have been built up by the whole of the light following the instant when the edge reaches the point in question — i.e. by the area shown shaded. Exposure E is normally defined as Intensity $I \times$ time t, but since in the case of a flash, I is a function of t, E must be defined by the relation

$$E = \int_t^\infty f(t) \cdot dt \qquad (1)$$

This is for the leading edge of the disk in the case of a camera photograph. For the trailing edge in the same case the following relationship will hold:

$$E = \int_o^t f(t) \cdot dt \qquad (2)$$

In the case of a shadowgraph Eq. (1) applies to the trailing edge and Eq. (2) to the leading edge.

Thus from a plot of the density profile of the image of either the leading or trailing edge of the disk appropriately transformed to a curve of Exposure vs. Time, the flash-time curve may be obtained by differentiation. In practice the leading edge was used in the case of a photograph and the trailing edge in the case of a shadowgraph, since with these the major portion of the blur occurs at low densities which are more easily measured.

It was found that the curves of Exposure vs. Time which were obtained had very steep gradients and that in consequence the derivative was difficult to obtain in practice. To overcome this difficulty the differentiation was actually performed on a Log Exposure vs. Time curve such as that shown in Fig. 4, and use was then made of the relationship:

$$\frac{dE}{dt} = E \cdot \frac{d(\log E)}{dt} \qquad (3)$$

Apparatus

The Tube Sensitometer and the Rotating Disk. The tube sensitometer and its associated matte white, diffusely reflecting screen were disposed so that only light reflected from the screen could reach the film. The sensitometer itself, which is shown in Fig. 6, consists of six horizontal rows of tubes let into the surface of a brass plate. Each row consists of ten tubes 4 in. long, each tube having an entry aperture at one end, and an exit aperture at the other. All the entry apertures lie in a common plane and all the exit apertures in a parallel plane. The film strip to be exposed is placed over one of the horizontal rows of exit apertures and, therefore, receives an exposure over ten different circular areas along its length. The intensity of each of these exposures is proportional to the area of the corresponding entry aperture, since the only source from which illumination is received is the diffusely reflecting screen. In a given row of tubes the areas of adjacent apertures differ by a factor of two, and the intensity range covered is therefore 1 to 512, or a log exposure range of 2.709. The circumferences of both entry and exit apertures is chamfered on the side facing the incident light so as to eliminate edge reflections, and the internal walls of the tubes are lined with dead black velvet, thus reducing reflections from these walls to the absolute minimum.

This type of sensitometer was used at first in order to eliminate any uncertainties in the spectral quality of the light reaching the film, which would be introduced by any lack of neutrality of the step wedge in a sensitometer of the intensity-modulated type (a time-scale sensitometer is, of course, not possible in this case). In the case of the tube sensitometer the spectral quality of the light reaching the film is controlled by the spectral reflectance of the matte white screen used in conjunction with it, which consisted of magnesium carbonate. This was as shown in Fig. 7, relative to magnesium oxide.

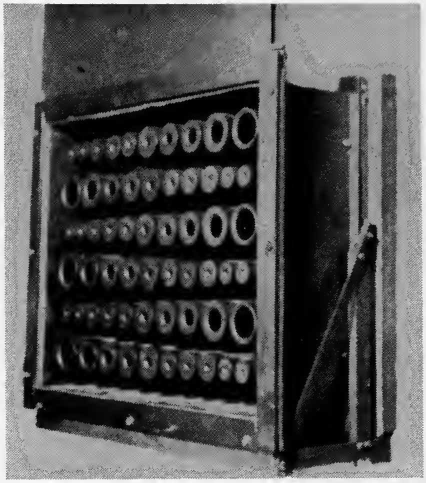


Fig. 6. Tube sensitometer.

Ideally it would have been desirable, in the case of camera photographs, for

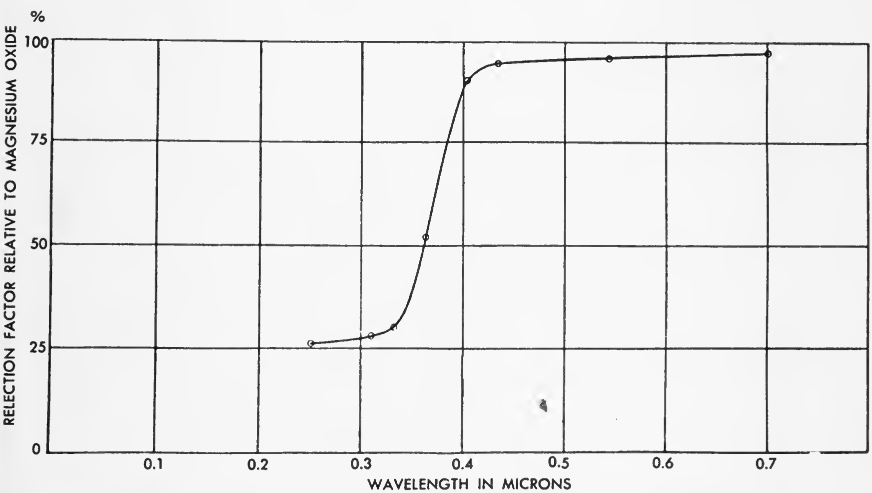


Fig. 7. Spectral reflectance of magnesium carbonate screen.

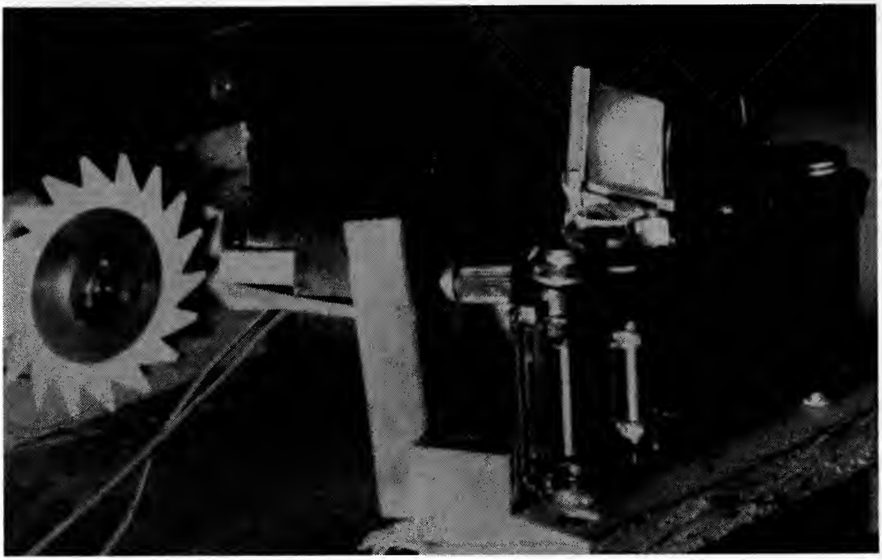


Fig. 8. Camera, disk and driving motor.

the reflecting surface of the disk to be coated with the same material as the screen so that the spectral reflectance of both would be exactly the same. It was found, however, that a satisfactorily clean edge could not be achieved on the disk when it was coated with this material. The disk, which was made from aluminum foil five thousandths of an inch thick coated on each side with white paper, was therefore smoked with magnesium oxide. The reflectance of magnesium oxide in the ultraviolet is considerably higher than that of the magnesium carbonate screen coating, as Fig. 7 shows, but it was considered that since this reflected ultraviolet would be largely absorbed by the glass of the camera lens, any difference remaining would be too small to cause significant variation of the contrast rendition of the film in the camera from that expressed by the characteristic curve derived from the sensitometric strip. This is the only condition which must be satisfied. Several light-time curves were obtained using this disk but it was found after a few runs that windage and centrifugal force removed the magnesium oxide.

An experiment was therefore made with another disk made from aluminum photographic foil, also five thousandths of an inch thick, but coated on one side only with a very thin pure white enamel overlaid with clear emulsion. It was found that with a given flashtube the curve obtained was sensibly the same as that given by the other disk, and so the enamelled disk was adopted and used for a considerable portion of the work. The form of this disk can be seen from Fig. 8 which shows the camera and disk with driving motor as a whole, and also from Fig. 1 which is a reproduction of a typical disk picture. The aluminum foil was 10 cm in diameter and it had 18 "teeth" of the form shown. One of the edges of the teeth was arranged to be radial. In the case of pictures taken with the camera this was made the leading edge since the blur appears ahead of the tooth. In the case of shadowgraphs the reverse holds, and for these the disk's direction of rotation was such as to make it the trailing edge.

The foil was clamped between duralumin disks 6 cm in diameter to keep it flat and ensure truth when it was running. This was essential, as the depth of field of the camera was very small at the short distance at which it was used. Considerable care was taken over the accuracy of the boss and of the disk as a whole, and dynamic balancing was found to be unnecessary.

The face of the disk was 2 ft from the flashtube and for camera photographs the angle of incidence of the light was about 30°

At a later stage in the work, when the shadowgraph technique was employed, the tube sensitometer was replaced by an ordinary photographic step wedge when it had been proved that in combination with the shadowgraph it produced results consistent with those obtained previously.

The Driving Motor and Measurement of Speed. The disk was mounted on the shaft of a high-speed motor. The speed obtained ranged up to 27,000 rpm but, in the interests of the life of the motor and safety, it was generally run at approximately 20,000 rpm.

The speed of rotation at the instant of firing the flash was measured electrically. The method of picking up the signal from the motor is shown in Fig. 9. An armature was mounted on the end of the shaft opposite to the disk and arranged to run between the poles of a double-wound electromagnet. A small d-c polarising current was passed through one winding and the resultant a-c signal taken from the other. The resultant signal frequency, which was twice that of the motor speed, was compared with a variable known frequency from a beat-frequency oscillator. An independent approximate mechanical check of the speed was made by means of a tachometer to ensure that the setting was not being made on a multiple or submultiple

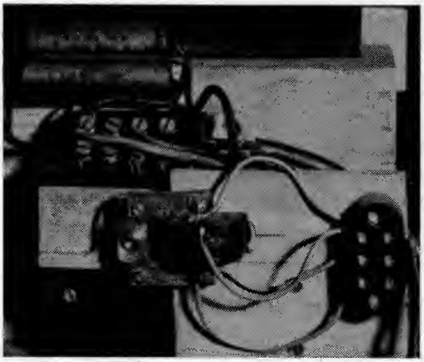


Fig. 9. Equipment for measuring speed of rotation.

of the correct frequency. The accuracy of the measurement was limited by the unsteadiness of the motor but readings to within 10 cycles/sec, or 2% approximately, were obtained.

The Camera. For the photographs the camera used was a 35mm reflex type with 7.5-cm lens operating at a reduction of 1.274:1. The aperture used ranged from $f/8$ to $f/22$ (as marked on the lens, i.e. not compensated for the extra extension), according to the speed of film used. The shutter was set to "time" and remotely operated by a solenoid. The exposure was chosen to result in a density of the black background at or near fog level. The speed of the image on the film plane was, for maximum speed of the motor, of the order of 100 m/sec.

Measurement with the Microdensitometer. The microdensitometer which was used is a nonrecording instrument using a barrier-layer cell and intended for use with spectrographic plates. To utilize the maximum range of the scale, it was adjusted to read zero density with the film base alone in the light path. This necessitated readjustment for each sample of film used. The effective width of the slit used was 0.025 mm and readings were normally taken at intervals of 0.05mm in the case of short duration flashtubes. The effective length of the slit is about 1.5 mm and it was adjusted to be parallel to the blur at the point where the greatest change of density occurred. The slit is moved linearly while the blur is, of course, radial. The error involved over the very short distance traversed (3 mm) is negligible.

For convenience the transmission scale, and not the density scale, was used, as the reading is easier. In addition, the transmission measured was specular and not diffuse. Neither of these factors is of importance as the transmissions of the sensitometric strip were measured in exactly the same way.

The grain of the film caused some scatter of the points, particularly at low densities; these were smoothed on the graph before applying further transformations.

The Meaning of the Ordinate Scale

It will be noticed, e.g. in Figs. 5, 20 and 23 that the final ordinate scales are expressed as "relative photographic effect" and not "intensity." Strictly the photometric term luminous intensity has a purely visual connotation and is a measure of the luminous sensation produced in the eye by a source of radiant energy. Now the quantity which has been measured is the effect versus time on certain photographic materials, of radiation from some flashtube sources. It is therefore, much more appropriate that the term "photographic effect" should be applied to this quantity. Others may prefer the term "photographic intensity."

The ordinate scale is relative and not absolute since only relative log exposure values are known. For this reason the ordinate scales are not comparable from graph to graph except in the cases of the three curves on Fig. 20 and the two curves on Fig. 23.

The ordinate scales can be drawn so as to be comparable with each other for various lamps used under various conditions by reference to the relative total light outputs of the flashes. The relative light outputs can be obtained by measuring the maximum densities produced in the disk pictures and then referring these densities to the appropriate sensitometric curve and reading off the relative total exposures. Since these readings represent the relative integrals under the final curves the appropriate ordinate scale can be determined. This procedure was followed to obtain Figs. 20 and 23 which are given as examples.

If desired, it would be possible to determine the ordinate scales in terms of equivalent intensity of, say, tungsten light or mean noon sunlight, or other source, such as gas arc, more nearly equivalent in spectral characteristics to a flashtube. This could be done by reference to sensitometric curves of the emulsions obtained with these sources at constant known intensities and known exposure times. It is unlikely that sufficiently high intensities combined with sufficiently short exposure times could be produced with such sources as to reproduce the reciprocity failure conditions which occur with flashtubes. It is doubtful, however, whether this is necessary or, for practical purposes, desirable, since for photographic purposes the flashtube intensity scale could be equally well expressed in terms of equivalent intensity at normal exposure times. In this way allowance would automatically be given to the effect of reciprocity failure.

The character of the final photographic effect vs. time curve is controlled by the relationship between the spectral quality of the light reaching the film and the spectral sensitivity of that film. It is desirable that this should be so since it enables the effect of films of different spectral sensitivities upon the duration of the flash to be investigated. It should be noted, however, that the character of the final curve is entirely independent of variations of gamma and shape of the sensitometric curve caused by any particular method of processing a given disk picture and its associated sensitometric strip. For this to be so, it is necessary only that both the picture and the strip should be given precisely the same processing of no matter what nature. Processing of any pair was in all cases by simultaneous brush development. This method gave the most consistent and reproducible results with comparatively simple apparatus. A comparison of two final curves, for the same tube and the same emulsion, obtained with markedly different development times and, therefore, different gammas, gave good agreement.

The Results Obtained (See Figs. 10–23)

The general characteristics of the flash from an S.F.7 or Arditron type of tube discharged under its maximum rated conditions of 2-μf capacity and 7.5 kv are exhibited by all the curves shown in Figs. 10 to 17. The position of the triggering pulse on the time scale is unknown. The main peak of the flash occurs about 2 to 3 μsec after the emission of light commences. This main flash is spent after about 8 μsec but is followed by a long "tail" at the comparatively low level of about 5% of the peak, which persists with appreciable magnitude up to about 30 μsec.

Detectable light output is present even after 50 μ sec but is too low to be shown easily on the graphs and much too low to be of practical significance.

Associated with this tail there is a secondary peak, small compared with the main peak, the relative height and time of occurrence of which vary somewhat from flash to flash. It usually appears at about 20 μsec. At this part of the curve the accuracy of the method is high and these variations in height and time do actually exist. Their cause is unknown.

Figures 10 to 15 show photographic effect — time curves obtained under

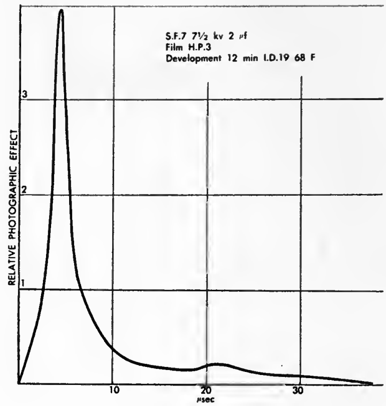


Figure 10

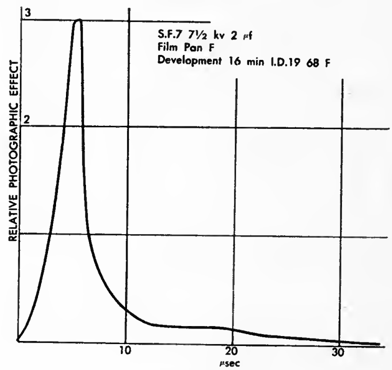


Figure 11

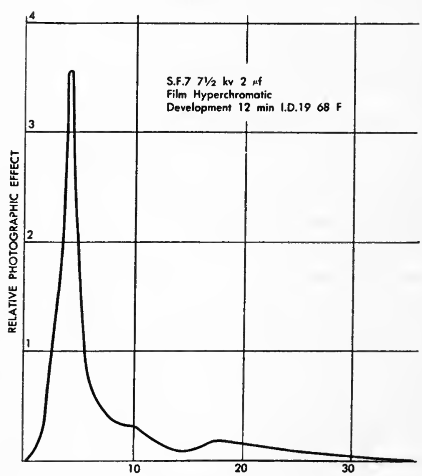


Figure 12

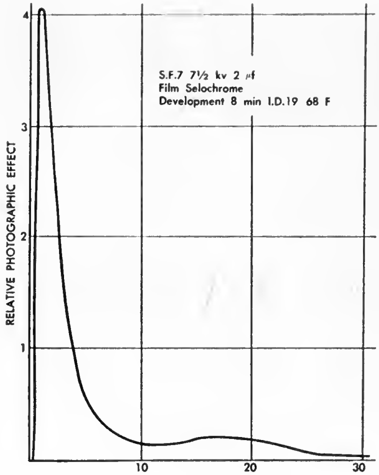


Figure 13

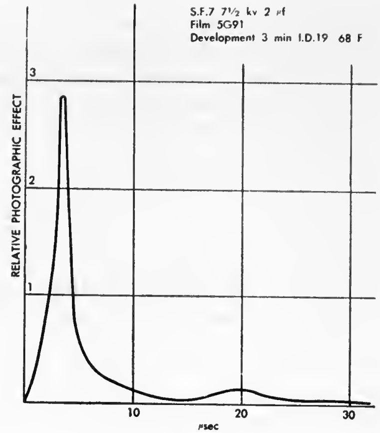


Figure 15

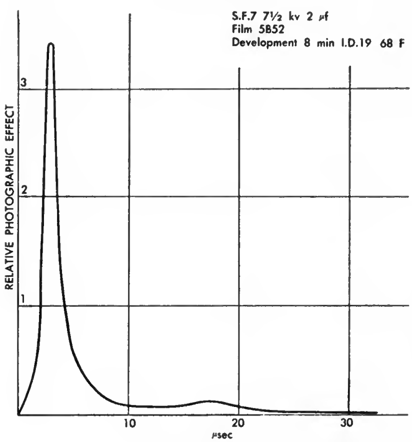


Figure 14

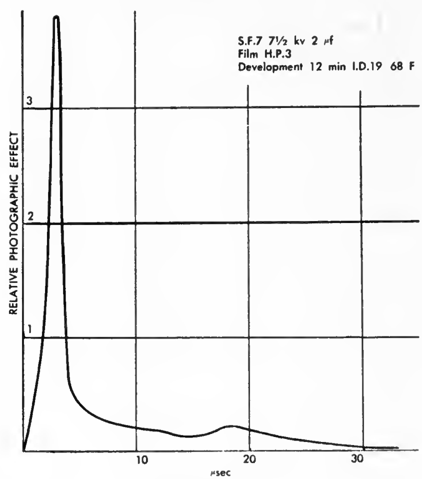


Figure 16

identical conditions for the flash of a Siemens S.F.7 tube, but recorded on several different emulsions. In all cases the capacity was 2 μf and the voltage 7.5 kv. These results were obtained with the earlier form of disk and in view of subsequent experience are regarded with some caution. This experience indicates that the rise time shown in the majority of cases is too long, and occasionally anomalous results, e.g. Fig. 13, were obtained.

From an examination of Figs. 10 to 15 there appears to be no significant advantage of effective flash duration with any of the six emulsions chosen which are of widely differing speeds and spectral sensitivity. In particular, there is no apparent advantage in any of the non-red-sensitive emulsions, a result which is in conflict with opinions expressed by others.

Figures 16 and 17 give a comparison between the Siemens S.F.7 and the

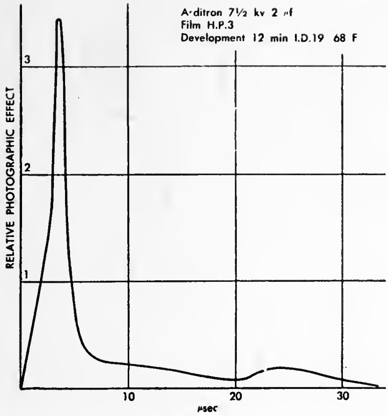


Figure 17

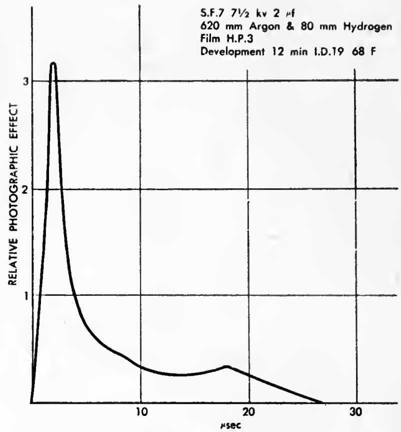


Figure 18

A.R.D. Arditron tubes under the same conditions on H.P.3 film. It is apparent that they have very similar photographic characteristics when flashed under these conditions, which represent their maximum rated power per flash. The total light outputs of these two tubes was found to be identical within experimental error. Their gas fillings were as follows:

S.F.7 — 590mm argon; 110mm nitrogen
Arditron — 613mm argon; 7mm nitrogen; 33mm hydrogen

Figures 18 and 19 show two S.F.7 tubes with nonstandard gas fillings. The relative light outputs of these tubes and of a standard S.F.7 were determined and the results, from which it appears that pure argon has a distinct advantage in this respect, were as follows:

Tube	*Gas Filling*	*Relative Light Output*
A	620 mm A	1.0
	80 mm H_2	
Standard S.F. 7	590 mm A	1.35
	110 mm N_2	
B	700 mm A	1.66

From the point of view of flash duration the standard S.F.7 and tube B are approximately the same. The effect of the hydrogen in tube A, however, appears to be to cause sudden complete

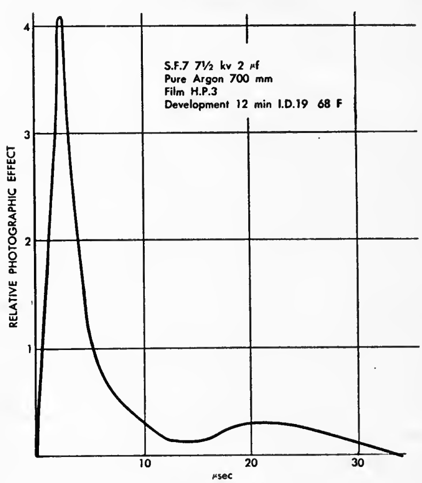


Figure 19

extinction at 25 to 30 μ sec, but the rate of decay over the earlier portion of the tail of the curve is less than with the other gas mixtures. It is of interest to note that this shorter tail was apparent from a visual comparison of the disk pictures. This more rapid cutoff is accompanied by about 30% decrease in photographic efficiency as compared with the standard S.F.7, whereas tube B has about 30% greater efficiency than the standard.

In examining the above curves it

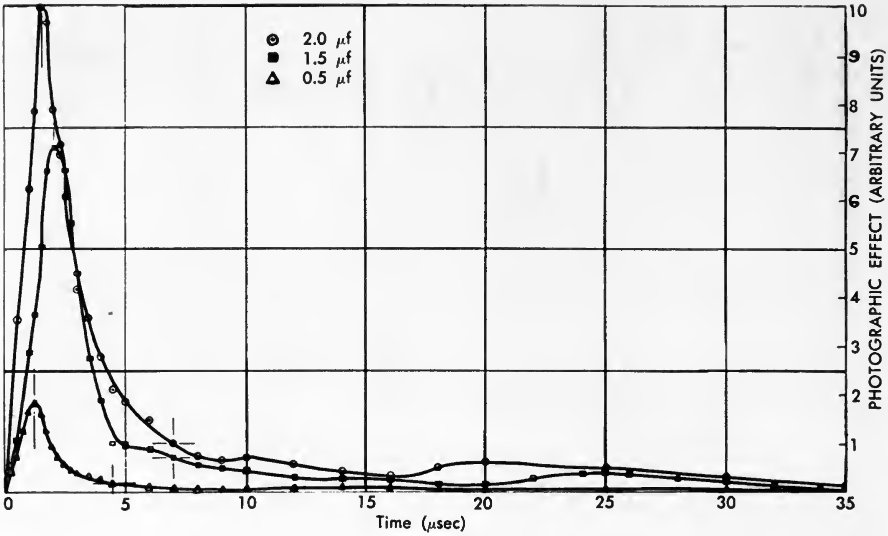


Figure 20

should be remembered that the peaks as plotted appear of different heights, and it is the ratio of this height to the height of the "tail" which is significant in considerations involving photographic duration.

Figure 20 shows the curves for a standard S.F.7 tube obtained by the discharge at 7.5 kv of capacities of 0.5, 1.5 and 2.0 μf. Within this figure the ordinates of the curves are comparable. There appears to be some decrease in the relative heights of the tail with decreasing capacity but there is no reduction in its overall duration. The secondary peak occurs later and is relatively somewhat smaller with smaller capacity. The duration of the main peak decreases considerably with capacity but not proportionately. The relative total light output in the three flashes was measured and is as follows:

	1st Flash	*2d Flash*	*3d Flash*
Capacity	0.5 μf	1.5 μf	2.0 μf
Relative total light output	1.0	5.4	8.1
Relative photographic efficiency	1.0	1.8	2.0

It is evident that for a fixed voltage and over a certain capacity range the photographic efficiency increases as a function of the capacity, ultimately, of course, reaching a maximum value. Extrapolation indicates that in this particular case this maximum is reached at approximately 3 μf.

Figures 21 and 22 show representative curves obtained with a Siemens S.F.2 tube under two different working conditions. For Fig. 21 the condition was as used in the Ernest Turner Electrical Instruments studio flash equipment with 100-μf condenser at 2 kv, and with a 6-ft cable between the condenser bank and the tube. This curve shows a flash duration which is very long compared with that of the S.F.7 types of tube as, of course, is only to be expected. The rise time would undoubtedly be shorter but for the inductive effect of the length of cable.

In Fig. 22 curve A shows the result for the S.F.2 tube mounted as closely as possible to the terminals of a low inductance 24-μf condenser charged to 2 kv. Curve B, which is reproduced for comparison purposes, was obtained

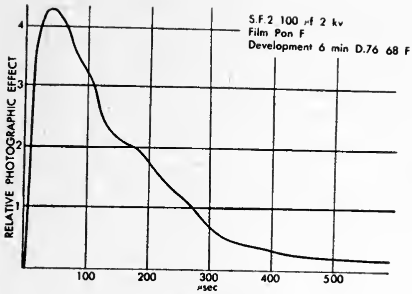


Figure 21

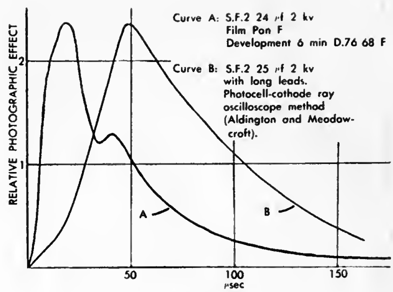


Figure 22

by Aldington and Meadowcroft[1] for the same tube using a photocell/cathode-ray oscilloscope system, the capacity in this case being 25 μf. The two curves have been plotted so as to have peaks of equal height. For the portions following the main peak the shape and duration are in general agreement, except that the secondary peak is absent from the photocell curve. There is a noticeable difference, however, in the rate of rise of light output shown by the two curves, the rise time in curve A being much shorter. This is not due to any fundamental disagreement, but to the fact that for curve B the circuit included comparatively long leads between the tube and condenser, which made the inductance greater than for curve A. This is illustrative of the very considerable prolongation of flash duration which is caused by the presence in the circuit of quite small inductance, and which can be seriously damaging to photographic results in experiments in which duration is critical.

The secondary peak which occurs during the decay from the main peak is again variable in position and magnitude from flash to flash as was found in the case of the similar secondary peak in the tail of the S.F.7 flash.

The results with the S.F.2 were obtained by running the disk at the comparatively slow rate of 3000 rpm. A slow film and low energy development were used to reduce the densities on the sensitometric strip to accurately measurable values. The much longer time scale rendered the whole derivation of the result much easier than with the short duration tubes.

Figure 23 shows curves for two experimental quartz tubes produced by Siemens, different capacities and voltages being used with each tube.[2]

The Accuracy of the Results

The accuracy of the results would be affected either by errors in the time scale or in the ordinate scale. The probable magnitude of such errors is discussed below.

The Time Scale. Errors of overall magnitude in the time scale are concontrolled by three factors: (a) the accuracy of the measurement of the speed of the disk; (b) in the case of camera photographs the measured reduction ratio in the camera, including film shrinkage; and (c) the accuracy of the microdensitometer movement.

Of these, (a) is by far the most serious. As mentioned earlier, the unsteadiness of the motor speed leads to an uncertainty in reading of $\pm 2\%$. In addition the accuracy of the oscillator used, when checked against a known source, proved to be $\pm 1.5\%$. As far as (b) is concerned, variatons in film shrinkage may amount to $\pm 0.5\%$, because of the variety of emulsions and bases used. The reduction ratio was not measured for each of these individually. Over the small range used, (c) is negligible.

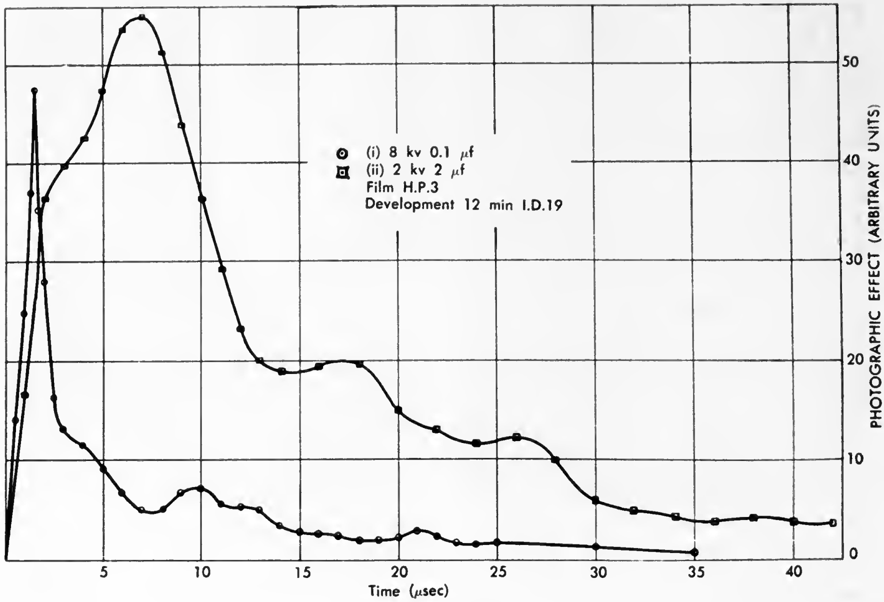


Figure 23

The maximum possible error from these causes is therefore ±4%. The linearity of the time scale is affected by variation of the speed of the disk during the period of the flash itself, which is certainly negligible, and also by the linear scan of the microdensitometer slit relative to the circumferential movement of the radial edge of the disk picture. Under the average conditions prevailing in the majority of the pictures this leads to an error in linearity of 0.5% which occurs toward the end of the scan, i.e. at the tail of the flash. This could be allowed for and corrected in the final curve, but the labor involved would not be justified by the very slight increase in accuracy resulting.

The maximum error in the time scale from all causes is therefore better than ±5%.

The Ordinate Scale. The primary factors affecting the ordinate scale are:

(a) Any departure from uniformity of processing between any one disk picture and its associated sensitometric strip.

(b) Accuracy of the transmission readings obtained from the microdensitometer.

(c) Error due to the slit of the microdensitometer not being parallel to the radial "edge" throughout its travel. This is separate from the error in the time scale mentioned above, although due to the same cause.

(d) Error due to finite slit width of the microdensitometer. This only occurs when the change in transmission with distance is nonlinear, i.e. particularly at the "shoulder" of the curve.

(e) Any unsharpness of the picture which might arise from a variety of causes.

Assessment of these errors is possible although in the case of that due to look of uniformity in processing only an estimate is possible, based on the consistency of the results. The effect of these errors on the final ordinate values obtained is, however, indeterminate, as the processes, already described, of smoothing, transforming and differentiating the graphs is to some extent dependent on individual skill. The amount of smoothing necessary depends largely on the grain of the image and thus varies from film to film. In addition the accuracy of the differentiation varies with the slope of the graph and thus varies considerably along the final flash curve.

The smoothing necessary on the Transmission vs. Distance graph affects particularly the first sudden drop in density. This gives rise to an indeterminacy in the position of the zero of the time scale which may possibly amount to as much as 1 μsec, and in general will tend to increase the apparent width of the peak.

The difficulties of differentiation lead in particular to an uncertainty in the height of the extreme tip of the peak owing to the high slope of the Log Exposure vs. Time graph at this point. This can amount to as much as $\pm 20\%$ and will influence the estimation from the final flash curve of the effective time of flash if this is taken as that time within which the height of the curve has fallen to some specified fraction of its peak height.

In addition the errors in the ordinate scale caused by the primary factors (a) to (d) listed above will influence the curve to an unknown extent but this extent is certainly small.

From the above considerations it is evident that the most reliable criterion of the overall accuracy of the results must be based on the consistency of a number of curves obtained for the same tubes under the same conditions. The value of repeat experiments is somewhat lessened by the fact that, in general, the flashes vary to a slight extent in successive discharges, even with flashes from the same tube under exactly the same conditions. However, a great deal of experience was gained in the calculation not only of Figs. 10 to 23 but also from many similar and repeat experiments. From this experience the conclusion has been reached that any characteristics actually present in the flashes which cannot be reliably detected, and which are therefore not revealed by the curves as plotted, are certainly of no significance in practical photography.

Acknowledgments

The authors wish to thank Dr. J. N. Aldington of Siemens Electric Lamps and Supplies Ltd. for his assistance in supplying the experimental types of flashtube, and G. S. Moore of Ilford Ltd. for arranging for the controlled processing of the film in his laboratories during the early stages of the work.

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Properties of Polarizers for Filters and Viewers for 3-D Motion Pictures

By L. W. CHUBB, D. S. GREY, E. R. BLOUT and E. H. LAND

High-quality projector filters and viewers are essential to full audience enjoyment of 3-D motion-picture shows. Projector filters of improved type are now in production and constitute an excellent solution to the problems presented by high temperature and high light intensity. Being glass-laminated, they are easily cleaned and thus should last indefinitely. Viewers of excellent polarization characteristics, color neutrality and stability are available. Some minimum performance specifications are proposed, in the interest of insuring that all spectators are enabled to see 3-D presentations with full effectiveness. Optical "leakage" and chemical instability, present in some types of viewers are especially to be avoided.

THE MEDIUM now being employed in the exhibition of stereoscopic or 3-D motion pictures is polarized light. Polarizing filters are placed in front of the two projectors and polarizing viewers are worn by the spectators. If the orientations of the projector filters and viewer lenses are arranged correctly, each eye sees only that image intended for it.

Whereas natural, unpolarized light is believed to consist of wave vibrations in random directions at right angles to the direction of propagation, linearly polarized light consists solely of vibrations restricted to a single plane. Such a change in characteristic of a light beam may be accomplished merely by interposing a linearly polarizing filter. It is unavoidable that such a filter diminish the brightness of the beam, since the resolution of the many random electric vibrations into a single plane causes at least half of the energy to be lost, usually by absorption. The action of the polarizer is practically independent of wavelength, so that no appreciable change in color is involved. In a polarizing filter, that azimuth which corresponds to the plane of vibration of the emerging light is termed the transmission axis of the filter.

When two such polarizers are superimposed with their corresponding axes parallel, the light transmitted by the first is for the most part freely transmitted by the second. But if the filters are superimposed with their axes at right angles, the second filter blocks passage of substantially all the light which has emerged from the first. Thus parallel polarizers transmit light, crossed polarizers block it out.

The effects described are not dependent upon having the two filters superimposed or even adjacent to one another. They occur equally efficiently when the filters are widely separated, and indeed the principle continues to

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Presented on October 8, 1953, at the Society's Convention at New York by L. W. Chubb (who read the paper), D. S. Grey, E. R. Blout and E. H. Land, Research Laboratory, Polaroid Corp., 730 Main St., Cambridge 39, Mass.
(This paper was received Nov. 20, 1953.)

apply even when the light emerging from the first filter reaches the second filter by virtue of being reflected from a plane surface of appropriate type and orientation.

This arrangement is employed in the two-film system of 3-D presentation. The beam from a given projector is polarized by passage through a fixed filter placed close to the projection lens. The beam then strikes a polarization-conserving screen at near-normal incidence and is reflected to the patron — who wears a viewer having polarizing lenses oriented so that one will admit the light and the other will block it. Thus only one eye sees the image. Since the second projector's beam is polarized at right angles to the first, its light enters the patron's other eye. Thus the condition is fulfilled that each eye will see the image intended for it and will be unable to see the image not intended for it.

In such a system, two properties of the polarizing filters become of major importance: luminous transmittance, and leakage. The luminous transmittance, k_v, which is simply the transmittance found when the incident light is entirely unpolarized, should be as great as possible to permit maintaining adequate picture brightness, without placing too great a burden on the projector arc, the projector lens system and the theater screen.

A filter's k_v value may be measured directly by any of a number of simple methods, or it may be computed as half the sum of k_1 and k_2, the partial transmittances for 100% linearly polarized light whose vibration direction is chosen so as to give maximum and minimum transmittance, respectively.*

The theoretical upper limit on k_v is 50% if surface-reflection losses are neglected, or about 45% if reflection losses of normal magnitude are taken into account.

The leakage of a pair of crossed filters should be as small as practicable to minimize the amount of light from the "wrong" picture reaching a given eye. Any appreciable amount of unwanted light produces double-imaging, or ghost images, which interfere with the enjoyment of scenes containing high contrast. The leakage, or k_{vx} value, of a filter may be measured by carefully crossing two identical filters and measuring the transmittance of the pair for unpolarized light, or may be computed as the product of k_1 and k_2. In making the necessary measurements some care must be taken since the transmitted light, besides being very faint, may lie mainly at wavelengths near the extreme ends of the visual range of the spectrum. If a photocell is used as detector, its spectral response must be matched very closely to that of the eye. The light source used must closely resemble C.I.E. Illuminant C.†

So far we have been considering the projector filter and viewer filters in combination. Let us now consider each separately, in greater detail.

Projection Filters

In the art of manufacturing highly efficient linear polarizers,‡ it is well known that a filter's luminous transmittance, k_v, can always be increased at the expense of allowing some increase in the leakage, k_{vx}. Conversely, the leakage can be reduced at the expense of reducing the luminous transmittance.

Using appropriate materials and meth-

* For a technical discussion of the formulas applying to linearly polarizing filters, see C. D. West and R. Clark Jones, "On the properties of polarization elements as used in optical instruments. I. Fundamental considerations," *J. Opt. Soc. Am.*, *41:* 976, 1951.

† Discussed in *The Science of Color* by the Committee on Colorimetry of the Optical Society of America. Thomas Y. Crowell Co., New York (1953).

‡ E. H. Land, "Some aspects of the development of sheet polarizers," *J. Opt. Soc. Am.*, *41:* 957, 1951.

ods, it is possible to achieve simultaneously a high transmittance and a small leakage. For example, filters can be made which have luminous transmittance, k_v, of 43% and a k_{vx} value of 0.4%; or the manufacturing method may be altered so that k_v is 40% and k_{vx} is 0.1%; or the k_v value may be made 30% and the k_{vx} value approximately 0.001%, or one part in one hundred thousand. For filters prepared with especially great care, even more striking pairs of values may be obtained. The values given here are representative of what can be achieved in routine production.

As a result of trying many grades of projector filters in a large number of theaters, we are convinced that a good projector filter can and should have a luminous transmittance k_v of approximately 40% and a k_{vx} value of approximately 0.03%. While no formal standards are recommended at this time, it is clear that these particular goals are reasonable and desirable.

Besides having satisfactory polarization properties, the projector filter must be of high optical quality. It must have sufficient clarity and uniformity (resolving power) that when inserted in the projected beam it causes no appreciable change in the sharpness of the image appearing on the screen. It must be neutral in color, so as not to disturb the colors of the various objects portrayed.

Plastic filters meeting these requirements can be produced readily. However, such filters are difficult to clean, as they are easily scratched. Thus a periodic replacement scheme must be adopted, which is neither convenient nor economical.

Our present policy is to provide projector filters of essentially permanent type. These become a regular part of the projection-booth equipment, and can be cleaned simply whenever necessary. They are Polaroid K-sheet filters, whose resistance to heat is outstanding. (The filter was developed especially to withstand light and heat such as would be encountered by an automobile headlamp filter used for many years in Florida sunshine.) The K-sheet layer is laminated between two thin, polished pieces of plate glass. Thus the filter can be cleaned in the same way that an automobile windshield is cleaned. The optical resolution is excellent, corresponding to about 15″ of arc. The color is almost perfectly neutral.

In making and using glass-laminated projector filters some precautions have been found necessary if strain effects are to be avoided. Any permanent strain existing in the glass layers tends to produce birefringence, with consequent interference with the polarization of the beam. Even if the glass contains no permanent strain, strain may be engendered by the temperature gradient resulting when the filter is heated unevenly by the very intense beam incident on the central area. An internal temperature rise to about 100 C was found in one test, for a filter used in front of a projector operated at 90 amp. Cooling the filter with a small blower reduces the temperature gradient; reducing the thickness of glass layers helps further.

The thin-glass laminated type of filter now being produced, if cooled with a small blower, constitutes a highly satisfactory answer to the projector filter problem. Production of this filter is being expanded, and the needs of the industry should be fully met before long. These filters are inexpensive and there appears to be no reason to use filters of less perfect performance and durability.

The filters are usually supplied in frames with small spirit levels attached, to insure mounting at the correct orientation, i.e., with the upper edge of the frame strictly horizontal. When this is done, the filter's axis will have exactly the desired direction (+45° for the right projector filter and −45° for the left projector filter). If the projector axis is directed downward at an angle of more than 20° from the horizontal, the filter should be tilted so as to be perpendicular to the beam. Ordinarily, however, the filter is mounted in the vertical plane; this is easier to accomplish, makes for easier leveling of the upper edge of the filter and tends to reduce the amount of dust settling on the filter. The polarizing function is essentially unimpaired.

Whenever any appreciable variation in luminous transmittance exists among various filters from a given lot, the right and left filters are "paired" so that the two members of a pair have the same transmittance within a few percent. Any appreciable mismatch as to transmittance would tend to produce imbalance in brightness observed by a patron's two eyes, and would interfere with his enjoyment of the show.

Viewers

Unlike projector filters, the 3-D viewers are not a part of the theater property and pass out of the control of the exhibitor when given to the patrons. Their quality, however, is of just as great importance to realistic 3-D presentation as any other component of the exhibition. On the other hand, the number of viewers used is so large that the urge to achieve the greatest possible manufacturing economy is great.

Several unsatisfactory grades of viewers have been distributed in some theaters in recent months. In the effort to save fraction-of-cent amounts in the manufacturing cost of the viewer, the producers of these viewers have caused patrons to see shows under conditions far from optimum, which damages the growth of the 3-D medium.

Perhaps the most important optical characteristic of the viewer is its ability to transmit the wanted beam with good efficiency. A luminous transmittance of approximately 40% is easily obtained, and without allowing excessive leakage. Perhaps a value of 35% should be set as the lower limit, since a filter having less transmittance than this darkens the picture harmfully and unnecessarily.

The ability to exclude the unwanted beam is also of prime importance. Since a k_2-to-k_1 ratio as low as 0.6% is easily achieved, there is no reason to accept a leakage (k_{vx}) value greater than about 0.3%. Any greater leakage tends to produce ghost images which, in sharply focused, high-contrast scenes, tend to become a source of real annoyance. The annoyance is especially great if the spectator is seated near the screen, if there is substantial lateral separation between the right-eye and left-eye pictures on the screen, and if the screen is bright while the ambient-light level is low. Here, as for other specifications, an inferior product may seem reasonably acceptable in many situations, but in combination with other short cuts will produce a significant overall reduction in audience enjoyment. Any harmful short cut yielding only infinitesimal saving in viewer cost seems unjustifiable.

The following table lists k_1 and k_2 values for different wavelengths throughout the visible spectrum, for samples of *H* and *K* polarizers which have overall luminous transmittances of about 40%:

Wavelength ($m\mu$)	*H polarizer* k_1	*H polarizer* k_2	*K polarizer* k_1	*K polarizer* k_2
400	0.45	0.02	0.5	0.001
450	0.75	0.01	0.7	0.000
500	0.8	0.001	0.8	0.000
550	0.8	0.0000	0.8	0.0000
600	0.75	0.0000	0.8	0.0000
650	0.75	0.0000	0.85	0.0000
700	0.8	0.0000	0.9	0.01

The axes of the viewer lenses are intended to be at right angles to one another, at plus and minus 45° from the horizontal. Our experience indicates that a 4° variation in the intended 90° angle between the lenses' axes is permissible. Greater variation may produce appreciable double-imaging.

Since many persons presumably tilt their heads slightly and unconsciously so as to roughly minimize double imaging, it is probably reasonable to allow some variation in the disposition of the centerline of the "v" orientation of the two filters. It is believed that the centerline, nominally vertical, may be allowed to deviate 4° either side of the vertical. As it is a simple matter to make the lenses essentially neutral in color there would appear to be no reason for accepting viewers off-neutral to any appreciable extent.

As in the case of projector filters, optical quality of viewer polarizers should be uniformly high. Such defects as haze, striae, orange peel and waviness should be minimized to avoid any appreciable effects on resolution and visual acuity.

The chemical stability of certain types of viewer lenses appears to be low. For reasons of economy, viewer lenses usually consist of thin plastic sheets, with no protective layers of glass. Furthermore, the polarizing layer itself may be an exposed layer. For such viewers it is essential that the polarizing layer have good stability. Otherwise, the filters may deteriorate during storage, especially in warm, damp environments. Also, handling by the patrons' fingers, especially during hot weather, may cause the polarization to fade before the show is half over. Many such instances have been encountered, and the damage done is especially great if the patron attributes his difficulty to 3-D in general, instead of to faulty viewers. We believe it necessary and desirable to specify that viewers shall not show appreciable deterioration in the respects discussed in the previous paragraphs, when exposed to high temperature combined with high humidity. We propose as a test procedure a 48-hr exposure to 90 F, with the relative humidity 95%.

Acknowledgments

In our projector filter and viewer programs we have been greatly encouraged by R. T. Kriebel and J. Turner, and by the skill and perseverance of our technical group, especially J. Falt, L. Farney and H. Buzzell.

Discussion

Henry Roger (Rolab Photo-Science Laboratories): Are there any data available as to comparison between the sheet polarizers and the old-type Nicol prisms with regard to transparency and polarization?

Mr. Chubb: I have no data on hand, but there are data available which we would be very happy to supply.

Anon: The picture *Kiss Me Kate* has been completed in 2-D and 3-D, which leads to the question of whether there is any possibility of reducing the density of these filters. Losses of nearly 60% in 3-D have been reported, and also a great deal of degradation in color.

Mr. Chubb: Well, as I pointed out, it is necessary for a linear polarizer to absorb at least 50% of the light, and, when reflections are taken into account, 55%. We are recommending that the transmission be no lower than 35% and preferably 40%. That comes about as close to satisfactory performance as you can expect when you take into account the fact that the k_{vx} or value of the light extinction properties of the polarizers must be kept very low.

Anon: The difference in color was very noticeable when *Kiss Me Kate* was switched from 2-D to 3-D on adjacent screens. Everything seemed considerably duller, with up to 130 amp of light at times, on a very large screen.

Mr. Chubb: With regard to color, I can only say that our projector filters and viewer filters are essentially neutral. I do not know what type you were using. I had occasion to see that picture in Hollywood and John Arnold thought that under the conditions in which it was presented there it was quite fine.

Anon: The preference of many Hollywood viewers for this picture in 2-D cannot be ignored . . . . Normal neutral filters are used to soften effects. Instead of using small stops when shooting, the filter is used to reduce contrast. Even in Technicolor we use a filter. So it would seem that polarizing filters could be similarly employed.

Mr. Chubb: I think we all agree that one of the unfortunate things about the use of polarizers in 3-D projection is that they do absorb light. We must build up the arc intensity, use low *f*-number lenses, and take every dodge that we can to get light on the screen. We must use not only 3-D screens, but 3-D screens which have high reflectivity. That is a real problem. What we are recommending here is that the very most be made out of the art of polarizer manufacture so that light on the screen will not be compromised nor colors distorted or softened.

Screens for 3-D and Their Effect on Polarization

By W. A. SHURCLIFF

A 3-D motion-picture screen, besides reflecting the two incident beams with good gain throughout a reasonably wide lobe, must conserve the polarization tagging of the beams. Tests on 100 screen samples show that the majority of screens of normal design meet these requirements excellently — for viewing angles not exceeding about 20° from the screen normal. Thus these screens are very satisfactory for use in narrow theaters. For 45° viewing, such as occurs in wide theaters, screens of this type usually have rather low gain and their polarization defect values approach a harmful level. Lenticulated screens, however, tend to avoid these difficulties and thus go a long way toward solving the wide-theater problem. There are several different designs of lenticulated screens, each having certain advantages and disadvantages.

A SCREEN for use at 3-D motion-picture shows must perform two functions: (1) reflect the two beams with adequate brightness gain throughout a lobe of adequate width, and (2) conserve the polarization of the two beams so that their polarization tagging will be intact when they reach the spectator.

The first function, serving as a diffuse reflector with adequate brightness gain and lobe width, has been studied by many investigators; an excellent summary of the general problem, terminology, etc., has recently been published by the Motion Picture Research Council.[1] The present survey has been focused mainly on the second function: conserving the polarization of the beams.

During the last six months, more than 100 screen samples have been tested. About one-third of these were commercially available screens, and the remainder were developmental samples submitted by screen companies, aluminum paint companies, etc. Some samples were submitted with the understanding that their exact identification would be withheld. A number of the samples had perhaps aged appreciably before being tested, and in these instances especially, the results apply, of course, only to the particular samples at hand.

The results on brightness gain will be presented first, to set the stage for the polarization conservation results.

Brightness Gain

The brightness measurements were made with specially designed test instruments requiring samples only 2 in.

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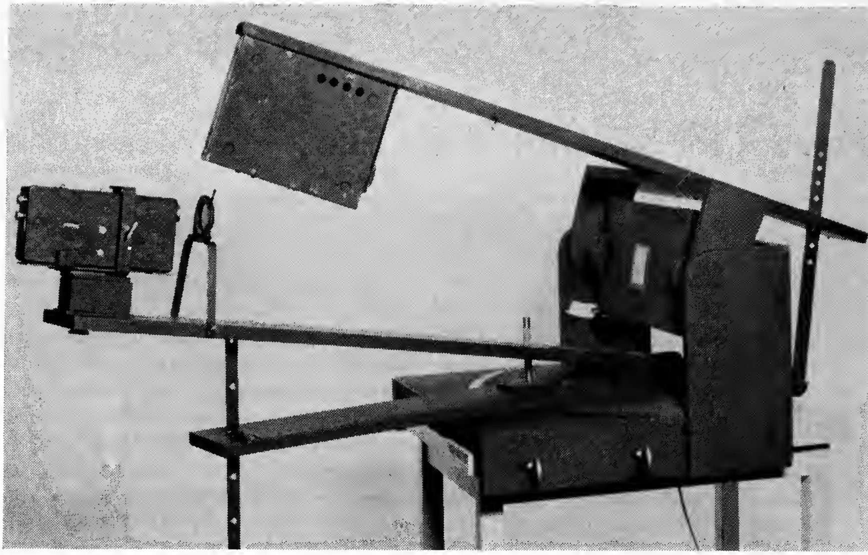


Fig. 1. Model 2 Screen Tester, general design.

square. The most versatile instrument, shown in Fig. 1, permitted setting the screen at any desired "tilt" angle from the vertical; also it permitted selecting any desired "projector" elevation angle from 0° to 35°, any desired spectator elevation angle from 0° to 35°, and any desired spectator *lateral* angle from 0° to 60° on either side of the screen normal.

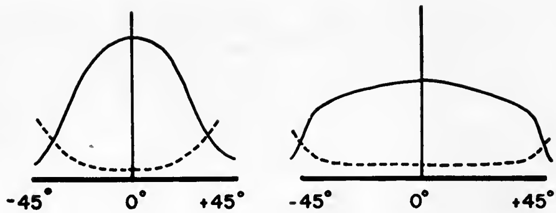
The "projector" consisted of a clear-envelope tungsten lamp used without lenses — to insure uniform illumination across the sample. The various brightness values were determined with the aid of a Luckiesh-Taylor footlambert meter.

At suitable intervals a clean block of magnesium carbonate was placed in the sample position and measured while being illuminated and viewed along the normal. The brightness value so obtained was arbitrarily called 100%, and the measurements made on screen samples were related to it. The resulting brightness ratios, referred to here as brightness *gain*, vary, of course, not only with the type of screen but also with the particular choice of sample tilt, projector elevation angle, spectator elevation angle, and spectator lateral angle (viewing angle). It should be emphasized: that the values refer to *brightness*, not *intensity* as in some other investigations; also that the method of measuring the brightness of the magnesium carbonate block differs slightly from that sometimes employed.

The results obtained may be summarized readily if we confine our attention to measurements made under the following "standard" conditions: (a) screen vertical, (b) projector elevation angle 0°, (c) spectator elevation angle 0°, and (d) spectator lateral angle 0°, 15°, 30° and 45° from the normal. The results are listed in the first four columns of Table I.

Screens of Normal Design. The first section of the Table deals with screens of "normal" design, i.e., smooth or near-smooth plastic sheets, plywood panels, etc., to which diffusing aluminum coatings have been applied. The second section deals with lenticulated screens,

Fig. 2. **Brightness gain vs. viewing angle for standard (left) and lenticulated (right) 3-D screens. Dotted curve represents the polarization defect.**



and the third deals with woven fabrics whose face consists of threads each of which appears to have its own individual aluminum coating.

The results shown in the first section of the Table indicate that screens of normal design almost invariably have a simple, bell-shaped gain curve, as shown in Fig. 2, with high gain at the center (viewing angle of 0°) and with gain falling off rather rapidly at viewing angles of 15° to 45°. It has recently been shown[2] that fall-off may be described approximately by an expression of the type: $(\cos\theta)^{s-1}$, where θ is the viewing angle and s is called the screen constant. The gain at 0° varies widely (150% to 800%) from one design of screen to another; and, as expected, the screens which have the highest gain at 0° suffer particularly rapid fall-off between 15° and 45°. Most of the commercial screens are of this type, and almost any desired 0° gain can be attained by proper choice of brand.

Surprisingly enough, almost all the screens of this group have approximately the same gain at 45°. And, unfortunately, the gain value in question is low, being 30% to 40% in most instances. For most theaters this is perhaps of little consequence; but it is a real embarrassment to theaters having unusually great width-to-length ratio ("wide" theaters). For such theaters an entirely new principle of screen design, known as lenticulation, seems called for.

Lenticulated Screens. Section 2 of the Table presents the results for lenticulated screens. These screens, instead of relying on randomly arranged microscopic particles of aluminum to spread the beam adequately, employ an array of *macroscopic* facets of carefully controlled (curved) shape. The facet surface may consist of clean bright aluminum, or a diffusing coating of aluminum paint, or a diffusing coating of plastic overlying a bright metal surface. Each type of design has its peculiar advantages and disadvantages.

Sample 34, a small experimental sample,* illustrates the very large amount of light that can be made available if the inefficiency usually associated with diffusing coatings is avoided — by dispensing with the diffusing coating entirely. The sample consists simply of a piece of bright, smooth aluminum foil in which thousands of small cup-shaped facets were embossed in a completely regular array by pressing against a specially machined mold. Each facet is rectangular in shape, 0.100 in. wide by 0.050 in. long, and the curvature corresponds roughly to part of a sphere of $\frac{1}{8}$-in. radius. The gain at 0° is 100%, which is scarcely notable; but instead of being a maximum here the gain actually increases with lateral angle up to 45°, where the gain is 400%. Beyond this angle the gain drops very sharply. The unusual brightness at 45° results in an annular "hot-spot" or "halo" which, of course, is undesirable. The halo is a result of the fact that each facet has a shape which is approximately, but not exactly, part of a sphere; and for every facet the de-

* This sample was prepared with the advice and encouragement of D. S. Grey.

Table I. Brightness Gain and Polarization Defect.

Screen	Brightness gain (%) for viewing angle of 0°	15°	30°	45°	Polarization defect (%) for viewing angle of 0°	15°	30°	45°
Section 1. Screens of Normal Design								
1. Normal type, Co. A	130	100	60	30	1.0	1.5	2.5	4.5
2. Normal type, experimental, Co. B	180	140	80	30	1.	2.	3.	5.
3. Normal type, experimental, Co. B	110	80	60	40	2.	3.	4.	7.
4. Normal type, experimental, Co. C	140	130	80	40	1.2	1.3	2.0	3.5
5. Williams, earlier type	280	210	70	30	0.2	0.4	1.0	3.5
6. Aluminized cardboard, Co. D	420	170	45	20	0.2	0.3	1.2	4.0
7. Aluminum paint on Masonite Prestwood, smooth side, Co. E	220	170	60	30	0.5	0.5	1.3	3.0
8. As above, but rough side, Co. E	60	60	50	50	4.0	4.0	4.0	5.5
9. Aluminum paint on plywood, Co. F	220	180	100	50	0.5	0.8	1.3	3.0
10. Aluminum paint on aluminum, Co. F	450	170	50	20	0.2	0.6	1.2	4.0
11. Beaver board aluminum-painted, Co. G	120	...	...	50	1.7	...	...	5.5
12. As above, but different paint formula, Co. G	100	90	70	50	2.0	2.0	2.5	3.3
13. Raytone, earlier type	110	90	60	35	2.0	2.5	4.5	6.0
14. Walker, earlier type	90	75	60	30	2.5	2.5	3.5	6.5
15. Normal type, experimental, Co. H	130	95	60	40	1.0	1.0	1.5	3.0
16. Da-Lite, earlier type	75	75	50	40	2.0	2.5	3.5	6.5
17. Normal type, experimental, Co. I	190	145	65	30	0.4	0.5	1.0	2.5
18. Aluminum paint on aluminum, Co. J	300	180	70	25	0.2	0.4	0.8	2.5
19. Aluminum paint on cardboard, Co. K	290	200	85	30	0.3	0.4	0.8	2.3
20. Raytone, earlier sample	270	180	90	30	0.4	0.5	1.2	3.1
21. Williams "Satin Silver #303"	310	260	95	45	0.3	0.3	0.8	2.5
22. Williams "Bright Silver #304"	650	360	70	25	0.2	0.3	0.8	3.1
23. Da-Lite	90	80	65	45	1.5	2.0	2.5	4.5
24. Bodde, earlier sample	370	250	75	30	0.3	0.4	1.2	3.5
25. Normal type, experimental, Co. L	330	180	70	40	0.4	0.6	2.0	4.5
26. Aluminum painted plywood, slightly rough surface, Co. M	310	...	...	35	0.3	...	...	2.5
27. As above, except smooth surface, Co. M.	870	250	...	15	0.1	...	...	4.0
28. Raytone Type 06, fresh sample	290	220	105	40	0.4	0.4	1.2	2.2
29. Walker #1, fresh sample	250	180	75	30	0.4	0.5	1.1	3.5
30. Walker #2, fresh sample	155	125	75	40	1.0	1.1	2.0	4.5
31. RCA All-Purpose	290	200	70	30	0.4	0.5	1.5	4.5
32. Aluminum coated with aluminum paint, Co. N	310	190	65	33	0.3	0.5	1.5	4.0
33. Same as above, slightly different design	550	215	60	23	0.2	0.5	1.6	4.0
Section 2. Lenticulated Screens								
34. Lenticulated, regular pattern clean bright aluminum facets, Polaroid experimental sample	100	100	200	400	0.3	0.3	0.2	0.2
35. As above, except facet shape is slightly different	95	80	80	90	0.5	0.5	1.0	1.0
36. As above, except facet shape is slightly different	180	150	120	120	0.4	0.4	0.4	0.4
37. As above, except facet shape is very different	600	500	200	100	0.2	0.3	1.0	3.0
38. As above, except randomly located facets of random shape	390	100	60	60	0.6	2.5	3.5	3.5
39. As above, but slightly different design	125	110	105	70	0.5	0.5	0.7	1.5

Table I. Concluded

Screen	Brightness gain (%) for viewing angle of 0°	15°	30°	45°	Polarization defect (%) for viewing angle of 0°	15°	30°	45°
40. Lenticulated, diffusing coating; experimental, Co. O	280	210	160	80	1.0	1.5	3.0	10.
41. As above, but different coating	450	450	180	50	0.1	0.1	0.5	4.0
42. Lenticulated, old sample, Co. P	320	180	60	25	0.5	1.2	4.5	22.
43. Lenticulated, old sample, Co. Q	105	105	105	45	0.7	0.7	0.8	2.2
44. Lenticulated, Miracle Mirror, old sample (?)	170	145	110	90	0.4	0.5	0.6	1.2
45. Magnaglow-Astrolite	175	155	135	110	1.6	2.0	2.5	4.7
Section 3. Coarse-Weave Screens								
46. Fiberglas cloth, not aluminized	60	60	60	60	20.	...	...	35.
47. Same, except each thread has an aluminum coating	50	50	50	50	10.	...	...	10.
48. Cloth sprayed with metal of unusual type	100	...	...	30	4.0	...	...	7.0
49. Aluminized cloth	70	60	50	30	10.	15.	20.	30.
50. As above, but different kind of surface	70	60	50	55	3.0	4.0	5.0	7.0
51. Coarse-weave cloth, aluminized	55	45	40	35	4.5	5.0	6.5	8.0
52. As above, but different type of cloth	110	80	35	15	3.0	4.0	6.5	14.0

parture from spherical shape is the same. It may be concluded in general that if each facet of a screen is to be of smooth aluminum and if all facets are to have the identical shape, any *microscopic* error in facet shape may produce intolerable *macroscopic* patterns.

The difficulty is avoided in Sample 39, an experimental sample in which the smooth aluminum facets have been made with randomly varying shapes and tilts. Here the gain is 125% at 0°, and still has the moderately large value of 70% at 45°. Because the facets are of random shape and tilt, no harmful halos result.

Sample 38 is of somewhat similar design, and has a gain of 390% at 0°. Sample 37 has a gain of 600% at 0° and 100% at 45°, but its lobe is extremely slender in vertical cross section.

In Sample 45, a sample of Magnaglow Astrolite screen, the bright, curved, metallic layer appears to be coated with a diffusing plastic layer, which presumably helps insure freedom from halos. The curvature of the metallic layer is different along lateral and vertical cross sections, so that the screen's lateral lobe is wider than its vertical lobe — in accordance with the requirements of most theaters. The lateral lobe is of considerable width: the gain at 0° is 180% and at 45° the gain is still as high as 110%; or about *three* times as great as for typical screens of normal design.

In Sample 44, a sample of the Miracle Mirror screen, the metallic layer appears to be of diffusing type, rather than smooth. The gain is 170% at 0° and 90% at 45°, this latter value again comparing very favorably with screens of normal type. (Unfortunately, attempts to obtain a really recent sample of this type of screen were unsuccessful.)

In general, lenticulated screens go a long way toward providing reasonably good gain even at viewing angles as great as 45°. Such screens appear uniquely capable of filling the needs of very wide theaters, and may prove useful in other theaters also.

Coarse-Weave Screens. The third section of the Table deals with screens whose front surfaces consist of distinct threads, each with its own aluminum coating. The samples were not noteworthy as regards gain and tended to produce lobes of irregular cross section.

Polarization Conservation

As is well known, the two projected beams of a 3-D motion picture are distinguished by their azimuth of linear polarization. By convention, the beam carrying the right-eye picture is polarized with its electric vibration at an azimuth of $+45°$ as judged by the projectionist looking past the projectors towards the screen. The left-eye beam is polarized at $-45°$. The lenses of the viewing spectacles consist of polarizers oriented so that the right eye receives only light having the $+45°$ azimuth, and the left eye receives only light having the $-45°$ azimuth. Thus if the projector filters, the screen and the viewers perform perfectly, the right eye will see only the picture intended for it, and the left eye will see only the picture intended for it; accordingly a stereoscopic, or 3-D, effect results.

Unfortunately, most actual screens degrade the polarization of each beam slightly, by virtue of diffraction effects, multiple reflection effects, birefringence effects, etc. As a consequence each eye of the spectator receives a little light from the beam meant for the other eye. The left eye, for example, will see brightly the picture meant for it and dimly the picture intended to be withheld from it. The latter picture, called the ghost image, is usually of low intensity and therefore of no practical consequence. However, the ghost tends to be more pronounced in situations where a white object is seen against a black background; here one edge of the ghost image overlaps the black background, enhancing the conspicuousness of the ghost.

A simple way to characterize a ghost of this most conspicuous type (white object on a black background) is to state its brightness ratio, or ratio of (a) brightness of the ghost image in an area where it stands alone, on a black background, to (b) brightness near the center of the image, where the right-eye and left-eye images overlap.

Ghosts can result from use of poor projector filters, poor viewers, or poor screens. It has been shown, however, that projector filters and viewers meeting very exacting standards are available and make only a negligible contribution to ghost images.[3] Thus the polarization conservation of the screen remains as the factor of principal interest.

The polarization conservation property of a screen may be defined in either of two ways: (1) affirmatively, so that a higher number indicates a better screen, or (2) negatively, in which case a higher number indicates greater damage to the polarization of the incident beams. The latter definition has been found more convenient, since smaller numbers are involved and they approach zero as the design of the screen becomes more nearly perfect. The quantity in question, called "polarization defect of the screen," or simply "defect," G, is defined with respect to the composition of the beam reflected from the screen in a specified direction when the incident beam is 100% polarized at $45°$ and is incident on the screen at a specified angle ($0°$ from the normal ordinarily). More exactly, it is the ratio of (a) amount of reflected light corresponding to the azimuth of minimum energy, to (b) total amount of reflected light. Roughly speaking, defect is the fraction of the reflected light which has the unwanted polarization.

Thus defined, the term *defect* has a direct and useful interpretation, being identically the brightness ratio of the ghost of a white object on a black background. For example, if the defect is 3%, the ghost's brightness ratio is 3% also. (The ratio will be even greater, of course, if the projector filters or viewers are imperfect, or if the viewers are worn at a nonoptimum angle.)

No formally established tolerance on

screen defect exists. Deciding on a suitable upper limit will be difficult since the noticeability of ghosts presumably varies with circumstances, such as screen brightness, contrast and density range present in the film, sharpness of focus, size of picture and distance of the observer. The spectator's absorption in the story is presumably an important factor also. Informal tests, however, suggest that a screen defect of $\frac{1}{2}\%$ permits essentially full enjoyment of the show, and even a 1% defect may be regarded as acceptable until better screens become available.

Since little or no information was available in the literature as to typical values of defect for commercially available 3-D screens, a general survey of the situation was undertaken. The same samples discussed above were measured, and the same equipment was used. For the present purpose, however, a polarizing filter was placed in front of the "projector," with the transmission axis at +45°, and a similar, rotatable, polarizer was placed just in front of the observer (meter). (Both polarizers were of sufficiently high quality that for purposes of the present tests they were essentially perfect; for example, a pair of such filters had a transmittance of less than 0.01%, when crossed.) For each viewing angle, measurements were made with the latter polarizer oriented so as to give the minimum reading (m) and then re-oriented so as to give a maximum reading (M). The defect is then easily computed, being (m)/(m + M).

The defect values obtained are presented in Table I, in the second group of four columns.

Screens of Normal Design. It is immediately apparent that typical screens of normal design have defect values of approximately 0.5% at 0° viewing angle. But it is equally apparent, as suggested by Fig. 2, that the defect increases almost tenfold as the viewing angle approaches 45°, where the defect is typically 3% to 5%. This is somewhat disturbing as it means that side-aisle spectators, when viewing scenes presenting maximum contrast, will be subjected to ghosts of 3% to 5% brightness ratio.

Inspection of the original brightness measurements shows that, for screens of normal design, the minimum reading m is almost independent of the viewing angle. This means that the defect increases with viewing angle — not because of *increase* in unwanted light but because of very large *decrease* in wanted light. Such a screen may be thought of as distributing unwanted light rather uniformly throughout a very wide lobe, while distributing wanted light throughout a narrow lobe. Perhaps the most obvious approach to improving the situation is to increase the amount of wanted light distributed at viewing angles of 30° to 45°. This again suggests lenticulated screens.

Lenticulated Screens. As expected, lenticulated screens appear capable of holding the defect value to a very low limit even for 45° viewing. Sample 34 (smooth bright aluminum facets) has a defect of 0.3% at 0° and only 0.2% at 45°.

Sample 45 (Astrolite, employing a plastic coating) has a defect of 1.6% at 0°, which is somewhat disappointing; at 45° the defect is 4.7%. If some means could be found for reducing the defect values, this screen would have a particularly striking performance.

Sample 44 (Miracle Mirror) has a defect of 0.4% at 0° and 1.2% at 45°. These values are unusually low.

It would appear reasonable to hope that some design will eventually be found which provides the wide brightness lobe of the Astrolite screen with the very small defect of the Miracle Mirror screen. A screen with these properties should be a superb solution to the wide-theater problem.

It may be, of course, that a hybrid design, intermediate between normal type and lenticulated type, would have some real merit. Indications were obtained that even in an otherwise normal screen the provision of a simple and informal pattern of small rounded hills and valleys made an enormous improvement for the observer at 45°.

Coarse-Weave Screens. As shown in Section 3 of the Table, poor results were obtained for nearly all samples whose front surface consisted of distinct threads, each with its individual aluminum coating. Polarization defect values of 5% to 15% were not uncommon.

In general, large defect values were found for all surfaces containing distinct threads, distinct grains, or sharp crevices. Presumably multiple reflections occur in all such instances, leading to an appreciable amount of depolarization. To avoid such difficulties it seems necessary to use a gently rounded surface with no sharp intervening crevices.

Plastic coatings on top of a metallic coating may exhibit slight birefringence in addition to causing some multiple reflections. Such coatings must be engineered carefully if they are to be successful.

(A number of experimental rear-projection screen samples were tested also. Besides having narrow transmission lobes they tended to produce large polarization-defect values.)

Conclusions

Screens of standard design, although having excellent gain and polarization conservation when illuminated and viewed near the normal, show poor gain when viewed at 45°. Hand-in-hand with the poor gain, a polarization defect of 3% to 5% is almost invariably found at 45°.

The lenticulated screen holds promise of being an excellent solution to the gain and defect difficulties at 30° to 45°. Use of clean, specular facets makes for particularly high gain and low defect, but may produce "hot-spot" problems. Employing microdiffusing mechanisms as adjuncts to the curved facets avoids these problems, but may increase the defect slightly.

It seems probable that further development of the lenticulated screen will produce a very satisfactory answer even for very wide theaters. For narrow theaters, screens of normal type appear to be very satisfactory in most instances.

Acknowledgments

I am indebted to R. T. Kriebel and W. H. Ryan for encouragement in this investigation, and to J. C. Gray for assistance in making many of the test measurements. I am indebted also to the various screen companies that supplied fresh samples of currently produced screens.

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Discussion

Ben Schlanger (Theater Consultant, New York): Both of the lenticulated screens mentioned are in symmetrical and linear pattern. What experience have you had with random lenticulation, with scattered directional effects?

Mr. Shurcliff: We've tried some experimental screens in which all the facets or cups were put on with random shapes and random orientations, and they looked very promising to me.

Anon: Do you have any information on rear-projection screens?

Mr. Shurcliff: I tried a few rear-projection screens and they seemed very disappointing. The brightness seemed to fall off quite rapidly and the polarization defect increased almost astronomically. I'm not sure I tried the best ones, but the ones I got hold of were quite disappointing.

George Lewin (*Signal Corps Pictorial Center*): When you mentioned the cloth screens, you said that polarization seemed to be greater in a vertical direction and also in a horizontal direction, because that's the way the threads ran. From limited experience, I should ask what's wrong with turning the screen 45° so the threads run the way you want them to?

Mr. Shurcliff: I'm afraid that if you turn it 45° you find good brightness diagonally but poor brightness vertically and horizontally. In any case, even though the brightness were adequate, we invariably have found in the coarse-woven samples we have tried, that the polarization defect is very large, being typically 10% and sometimes 20%, so that the double-imaging is intolerable. My feeling is that the light gets reflected several times in between the threads and loses its polarization.

W. W. Lozier (*National Carbon Company*): I saw one screen in particular where paneling or perhaps seams, I don't know which, made the screen surface visible. And in viewing a 3-D picture I had the impression that I was looking through a veil in order to see the picture in which most of the action was behind the screen. Your analysis doesn't take any account of that kind of defect, does it?

Mr. Shurcliff: I am afraid I have studied only brightness and polarization, but not the seams. The seams are very important, of course.

Dr. Lozier: It wasn't only seams, but paneling and the sort of thing that gave streaks that made it look as though you were looking through a curtain.

Leonard Satz (*Raytone Screen Corp.*): Just as there are problems in the transmission of the filters, we feel that we have problems in producing the type of screen that the exhibitor wants and which the patron is waiting to see. We have a problem in getting a screen of uniform surface and one which will give the greatest brightness to the most important section of the theater. We can all go to lenticulated surfaces. Designs are available which can do that very successfully, but if we do, we sacrifice the light that we need for good brightness and brilliance in the most important parts of the theater for those seats that we feel are the less important seats in the theater.

Mr. Shurcliff: That's a very good point.

John Volkmann (*RCA Victor Div., Camden*): What is the maximum percentage of polarization defect which you consider tolerable?

Mr. Shurcliff: Well, we at Polaroid feel that we would like to see the polarization defect no greater than very roughly 0.5%. We don't have a final figure to recommend, but we think it would be in that neighborhood. Of course, in scenes where the contrast is low, or the focus is not perfect, a somewhat larger defect seems to be not too harmful. But we would like to see it get down pretty close to 0.5% or less.

Howard Karp (*Radiant Manufacturing Corp.*): I'd like to correct a possible misunderstanding before it goes further and take the side of Dr. Shurcliff. We do not lose any light, as was just indicated, by using a lenticular surface.

Mr. Satz: I didn't mean loss of light. What I meant to infer was that greater brightness values are available without lenticulation. That I have proven to myself many times and independent laboratories have proved it for me. We know that we can get higher brightness gains and we know also that for a screen to give the proper performance in a theater with the use of projection-type filters and eyeglasses we have to have brightness gains that are quite high. Now, to compromise and take what you might consider a favorable brightness gain and then change the characteristics so as to lose brightness and snap in the picture, is to a screen manufacturer unforgivable. We feel that for stereo and wide-angle projection we have to give a brightness value to the theater that is equivalent at least to the best type of ordinary projection on smaller, white diffusive screens. That is very difficult to do unless you have a high brightness gain. At the moment we know of no way of getting it together with good brightness at the sides; nor can we get seamless construction by going at this time to lenticulated types of patterns.

Equipment to Measure and Control Synchronization Errors in 3-D Projection

By R. CLARK JONES and WILLIAM A. SHURCLIFF

Equipment is described that permits the projectionist to obtain and maintain perfect synchronism in the projection of 3-D motion pictures. This is accomplished without stopping the show or otherwise interfering with the continuity and quality of the projection. The equipment is of two basic types: synchronization monitors and synchronization controls. The monitor is used to measure the direction and amount of the synchronization error, and the control is then used to correct the error.

PRESENT MEANS of projecting 3-D motion pictures involve the simultaneous projection of two separate strips of film in two separate projectors. In order to project the two films in the same time relation as that in which they were exposed, it is necessary that the two projectors be synchronized, and that the two films be started in synchronism. It is further essential that if for any reason it is necessary to shorten one of the films, the other film must be shortened by exactly the same amount in the corresponding position.

Those of you who have seen a number of 3-D motion pictures, not in review rooms, but in ordinary theaters, are uncomfortably aware that all theaters do not always present 3-D pictures in perfect synchronism.

Present means of projection are inflexible. If the films are started wrongly, or if an incorrectly compensated splice occurs, the synchronism is imperfect and nothing can be done to correct it, short of stopping the show and rethreading on footage marks. Or, if the means used to interlock the two projectors introduces a fixed or variable error, there is nothing the projectionist can do to offset this error. A check of over 100 theaters has shown that about one-fourth of all 3-D motion-picture presentations have a disturbing lack of synchronism.

Synchronization errors are conveniently described in terms of the number of frames by which one projector is ahead of the other. If, for example, the right projector is running $\frac{1}{24}$ sec ahead of the left projector, the synchronization error is described by saying that the right projector is leading by one frame.

We have conducted a good many tests with a variety of 3-D films and with a number of observers to find out how serious synchronization errors are. The more critical observers find a synchroni-

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Presented on October 8, 1953, at the Society's Convention at New York by R. Clark Jones (who read the paper) and William A. Shurcliff, Research Laboratory, Polaroid Corp., 730 Main St., Cambridge 39, Mass.
(This paper was received Oct. 27, 1953.)

Fig. 1. Showing the Polaroid 3-D Electronic Sync Monitor, Model 21. The meter is at the left, and the photocell housing is on the right. The main electronic chassis (with 18 tubes and 5 relays) is in the center.

zation error as large as $\frac{1}{4}$ frame to be objectionable when fast action is involved. Uncritical observers may tolerate as much as $\frac{1}{2}$ frame if the action is not very fast. There is no question that all observers find an error of one frame to be seriously disturbing. With an error of one frame, all moving objects acquire a watery, transparent appearance that is very characteristic. This effect makes moving lips, blinking eyes and fast body motions look peculiar and disturbing.

A one-frame error, however, is not sufficient to make moving objects appear double; this requires an error of at least 2 or 3 frames.

Error of splicing and of threading up can, of course, produce synchronization errors of any number of whole frames. We have observed errors of 2 or 3 frames due to incorrect threading, and errors of 4 or 5 frames due to incorrect splicing of the film. Film exchanges regularly find splicing errors in 3-D films that are received back from theaters.

All the electrical interlock systems that we have seen have synchronization errors of not more than $\frac{1}{2}$ frame. A typical error is $\frac{1}{4}$ frame. Mechanical interlocks, however, may have much larger errors. We have encountered two installations of the flexible-cable type that have errors exceeding one frame.

All the synchronization errors described above were measured with specially developed synchronization monitors, of the types described below.

Synchronization Monitors

When synchronization monitors were first being developed, the possibility was explored of marking the films so that light signals could be picked off at the two projectors. These signals would be received by two phototubes, and the relative time of the two signals would be compared electronically.

The method was attractive at first, but was abandoned for two reasons: (1) Extensive modification of existing projectors would be required to pick off the light signals, each different type of projector requiring separate treatment; (2) The time delay between the development of the method and its effective use would be too great.

Accordingly, we turned our attention to methods that do not depend upon any special marking of the film.

Polaroid 3-D Electronic Sync Monitor, Model 21

The first Sync Monitor to be developed, the Model 21 device, is shown in Fig. 1. It includes a phototube housing, a large meter and the main electronic chassis. This latter component is fairly complicated, involving 18 tubes and five relays.

The Model 21 makes up for its complexity, however, by its simple, clean-cut performance. All that is necessary is to place the phototube housing so that it can look at the screen, plug the power cord into a source of a-c power, and throw the power switch. From then on, the meter reads the direction and amount of the synchronization error. If there is no error, the meter reads exactly zero, at the middle of the scale. If the right projector is ahead, the meter reads to the right of center, and if the left projector is ahead, the meter reads to the left. The meter covers the range between 5 frames error in one direction to 5 frames in the other direction. The meter scale is expanded in the middle so that small errors can be read easily and accurately.

If the two films have a synchronization error of more than $\frac{1}{4}$ frame in either direction, a buzzer starts to sound, and continues to sound until the error becomes less than $\frac{1}{4}$ frame.

The Model 21 Sync Monitor is responsive to sudden scene changes. Whenever there is a scene change, there is a sudden change in the overall screen brightness. The Model 21 responds to these sudden changes of screen brightness, while at the same time it completely ignores the 48 cycles/sec modulation of the screen brightness by the projector shutters.

The phototube housing contains two phototubes. The light from the screen reaches each phototube through a polarizer, and an $f/1$ lens. The polarizers are oriented so that one phototube receives light only from the right-eye image, and the other phototube only from the left-eye image.

The signal from each phototube is amplified separately by a circuit that provides a 1-msec pulse at the beginning of the projection of the first frame of a new scene. There are thus obtained two brief pulses, each of which represents the beginning of a new scene in one of the films. If these two pulses occur simultaneously, the synchronism is perfect, and the meter reads zero. If, however, the pulses do not occur simultaneously, the interval between them is measured by a special timing circuit and the result — the synchronization error — is displayed on the meter. Simply by looking at the meter the projectionist sees which film is ahead and by how much.

Polaroid 3-D Sync Monitor, Model E

More recently, a much less expensive type of 3-D synchronization monitor has been developed, which offers almost equally good performance provided the projectionist familiarizes himself with its use, and provided slightly modified projector shutter blades are used (Fig. 2).

The Model E device, operating on a stroboscopic principle, consists essentially of a slotted disk rotated at 60 rpm by a Telechron motor. A window is provided so that one can look through a portion of the slotted disk, and a split-field polarizer is placed over the window. The upper half of the field passes the right-eye image and the lower half passes the left-eye image.

Looking into the window, the projectionist sees two sets of stripes, each of which corresponds to $\frac{1}{48}$ sec, or $\frac{1}{2}$ frame. Thanks to the special modification of the projector shutter blades (slot made in the cutoff blade), every other stripe appears fluted, as shown in Fig. 3. If the stripe pattern appears as in Fig. 3, i.e., with the upper stripes not quite aligned with the lower stripes, the synchronism is imperfect.

Perfect synchronism appears as in Fig. 4. Unfortunately, this same pattern results if the synchronization is incorrect by an amount which is large and equals exactly one frame, or exactly two frames, or exactly any number of whole frames. Thus the projectionist must be qualified to distinguish perfect from grossly incorrect synchronism.

In using the Model E Sync Control,

Fig. 2. Showing the Polaroid 3-D Sync Monitor, Model E, with the Tell-Tale Filter. The photograph shows also two of the slotted shutters that are suitable for Simplex Standard and Super Projectors.

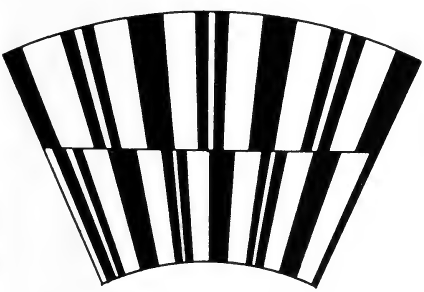

Fig. 3. Showing the appearance of the window in the Model E Sync Monitor when the left projector is leading by ⅜ frame. The white line down the middle of alternate stripes is due to the slot in the cutoff blade of the shutter.

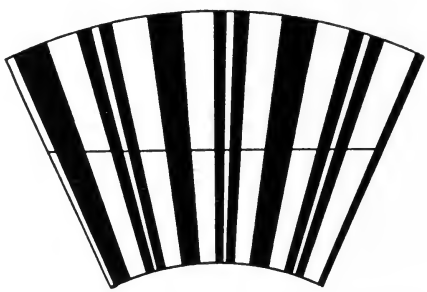

Fig. 4. Showing the appearance of the window in the Model E Sync Monitor when the synchronism is perfect. Note that the stripes above and below are perfectly lined up. This appearance in the Model E Monitor does not prove that the synchronism is perfect, however, but that it is either perfect, or imperfect by one or more complete frames.

the projectionist first adjusts the control so that the window appears as in Fig. 4. He then knows that the synchronism is perfect, or is imperfect by one or more full frames. He then puts on a pair of 3-D viewers, and looks at the screen. If fast moving objects have a clean, solid, sharp appearance, he knows that the synchronism is perfect. If, however, fast moving objects have a blurred, watery, transparent appearance, he knows that the synchronism is imperfect by one or more whole frames.

To correct imperfect synchronism, the projectionist changes the synchronization, *one full frame at a time*, and notes whether the watery appearance gets better or worse. By this means, the projectionist is able, in a shorter length of time than it takes to describe all this, to obtain perfect synchronism.

During the first showing of a new film, the projectionist should recheck the synchronism at frequent intervals to guard against the occurrence of a mismatched splice.

If the synchronization is in error by as much as two or three frames or more, the projectionist easily detects double-imagery in scenes containing fast action; for example, when a man raises his arm quickly, two arms appear to rise. When the synchronization error is as large as this, the *direction* of the error can be determined by a special Tell-Tale Filter mounted on the top of the Monitor. Seen through this filter, the right-eye pictures appear red and the left-eye pictures appear green. Suppose now a light-colored object, such as a hand, suddenly moves rapidly. If the red image begins to move first and moves ahead, it is evident that the right projector is leading, and conversely. Thus even when very large errors in synchronization occur, the projectionist readily finds what corrective action to take.

All this sounds complicated. But once the projectionist becomes familiar with the instrument (and this takes only 15 or 20 min of experimentation) the Model E Sync Monitor permits him to obtain and maintain perfect synchronism quickly and easily.

The modified projector shutter blades present no problem since a suitable pair, already modified, is usually supplied with each Model E Monitor.

The question: Which monitor is recommended? is easily answered. An ideal monitoring installation would include both the Model 21 and the Model E. However, in those applications where only a small outlay can be made, the Model E device should perform very well. Both devices have already been tried out in several theaters, and perform as intended.

Synchronization Controls

The basic purpose of a synchronization control is to adjust the synchronism between the two projectors.

Every synchronization control, however much disguised, is the equivalent of a mechanical differential. In fact, a mechanical differential is exactly what one needs to control the synchronization when mechanical interlocks are employed. In the type of mechanical interlock that employs a flexible cable, a gearbox is present in the middle of the cable. To obtain differential control, all that one needs to do is to mount the gearbox so that it can be rotated as a whole. One half revolution of the gearbox changes the synchronism by one frame if the cable rotates at 1440 rpm. We have constructed several differential controls of this type, and they are operating very well in the Boston theaters where they are installed.

Most theaters, however, employ electrical interlocks. They use General Electric Selsyns, or synchros of other manufacturers. In such installations the straightforward method of controlling synchronism is to use a differential generator. We have also developed a rotary six-position electrical switch that performs the same function.

Differential Generators

A differential generator is a special type of electric motor. It has a three-pole delta-connected rotor, and a three-pole delta-connected stator. The rotor is connected to the three-wire secondary of the synchro of one projector, and the stator is similarly connected to the secondary of the synchro of the other projector. When so connected, the synchronism of the two projectors can be controlled by rotating the shaft of the differential generator. If the synchros rotate at 1440 rpm, one revolution of the differential generator changes the synchronism by one frame.

The differential generator must be matched to the secondary voltage and the power frequency of the synchros. If, for example, General Electric 2JA33 or 2JA39 Selsyns are used, the General Electric 5MJ35CB Differential Selsyn should be employed.

We have modified a number of differential generators of both Stancil-Hoffman and General Electric manufacture, by fitting them with control knobs, and locks. One of these is shown in Fig. 5. In order to control the synchronism, one simply loosens the lock and turns the wheel slowly. One clockwise rotation of the control knob advances the right projector exactly one frame in 1440 rpm installations. After the adjustment is made, the lock is retightened (In installations where the synchros rotate at 1200 rpm, $\frac{5}{6}$ turn of the control knob changes the synchronism by exactly one frame.) Thus any synchronization error, large or small, is easily corrected.

The differential generator is probably the best method of synchronization control with electrical interlocks. It has the disadvantage, however, that a different type of differential generator must be employed for each type of synchro. Furthermore, it has the disadvantage of relatively high cost: about $280.00.

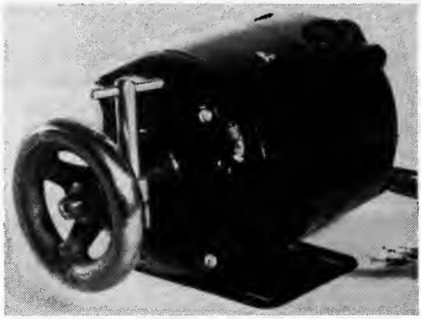

Fig. 5. Showing the General Electric Differential Selsyn 5MJ35CB1A (110 v, 60 cps) with a control wheel and brake added.

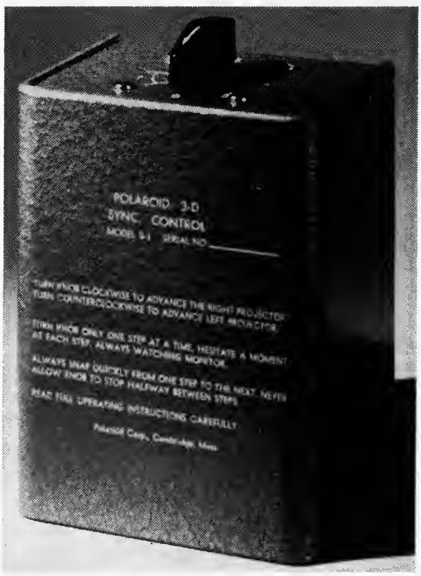

Fig. 6. Showing the Polaroid 3-D Sync Control, Model S-3. Six steps of the control (one complete rotation of the control knob) changes the synchronization by one frame. This Sync Control contains a rotary 5-pole 6-position motor-control switch of 10 amp continuous rating at 110 v, made by the Electro Switch Co.

Polaroid 3-D Sync Control, Model S-3

The primary purpose in developing the Model S-3 Sync Control shown in Fig. 6 was to provide an inexpensive substitute for a differential generator. It has turned out that the Model S-3 is very little inferior to a differential generator, and indeed, has some advantages over it.

Electrically, the Model S-3 is a 6-position rotary switch. The switch proper is a 5-pole, 6-position switch of the break-before-make type. The 35 terminals of the switch are wired to a 10-wire terminal strip. All external connections are made to the 10 contacts of the terminal strip.

The Model S-3 can be used only with single-phase synchros, of the usual (5-wire) type. It cannot be used with 3-phase synchros (6-wire) type. Except for this limitation (of very little practical importance), it can be used with synchros of any manufacture, of any secondary voltage, and with any power frequency.

When the switch is snapped from one position to the next, two functions are accomplished: (1) The primary connection of one of the synchros is reversed, causing a 180° rotation of the equilibrium position. (2) The connection between the 3-wire secondaries of the two synchros is cyclically permuted, causing a 120° rotation of the equilibrium position. The net effect is that each step of the control causes a 60° change in the equilibrium position of one synchro (and one projector) with respect to the other. Each step of the Control thus changes the synchronism by $\frac{1}{6}$ frame in 1440-rpm systems, or $\frac{1}{5}$ frame in 1200-rpm systems.

Because the Control provides a discontinuous adjustment of the synchronism, with steps of $\frac{1}{6}$ frame, it is not possible to obtain exactly perfect synchronism. It is always possible, however, to come within $\frac{1}{12}$ frame of perfect synchronism; this is three times better than is required by critical observers, and thus may be called perfect for all practical purposes.

The S-3 Control has the advantage that one does not have to look at the control knob to see how far it has been turned. By counting the steps mentally, one can look continuously at the window of the Model E Monitor while one is turning the knob of the Control. Also, no unlocking and locking operations are involved.

Finally, the Model S-3 Sync Control has the important advantage of low cost: about one tenth that of the differential generator.

Both the differential generator and the Model S-3 Sync Control can be used with entire success in installations which include stereophonic sound systems.

Conclusion

In summary, Polaroid has developed equipment that makes it possible to achieve and maintain perfect synchronism in the presentation of two-film 3-D motion pictures. The Model 21 Electronic Sync Monitor accomplishes this function in a manner that leaves little to be desired in the way of simplicity of performance. The Model E Sync Monitor accomplishes the same function very inexpensively, at the cost, however, of installing Modified Shutter Blades in the two projectors and of requiring a small amount of self-training on the part of the projectionist.

With the exception of the differential generators, all of the instruments described were developed from the ground up by scientists in the Research Laboratory of Polaroid Corporation. It is a pleasure to acknowledge the important contributions made by Messrs A. G. Carpenter, L. W. Chubb, J. A. De-. Young, J. C. Gray, D. S. Grey, Dr. C. H. Matz and M. Parrish, Jr.

Discussion

George Lewin (*Signal Corps Pictorial Center*): Is there a chance that the Model 21 would be affected if the illumination of one projector is much different from the other?

Dr. Jones: No, the two electrical channels, one for each eye, have independent AGC (automatic gain control) circuits. There can be a 10 to 1 difference between the two in practice and the equipment is in no way affected in its accuracy.

Mr. Lewin: Then, when you make the adjustment with the step control, do you have to wait for the next scene change to know whether you've gone in the right direction?

Dr. Jones: This is a complicated situation. First of all, you know quantitatively from the instrument how much of a correction to make and in which direction to make it. So usually on your first effort you have successfully corrected the sync error and you merely wait for the confirmation of the indicator that the error is zero. If, however, one wishes to follow the change as it is made, one uses the Model E device simultaneously and follows the change in sync as the correction is made with the sync-control switch. In fact, the ideal installation has both kinds of Sync Monitors.

Mr. Lewin: Is it possible that on certain scene changes there isn't enough change in density to give you an indication?

Dr. Jones: I'd say offhand that we get about three-quarters of all the scene changes

Mr. Lewin: In other words, you might be fooled sometimes if the change in density isn't sufficient from scene to scene. You might think that you're in sync, but actually be out.

Dr. Jones: There is a light on the meter case that flashes if, and only if, a new reading is obtained. Thus you always know when another reading is obtained. Furthermore, the meter holds the last reading. Thus if you have made a change in the sync since the last reading, you expect that the meter reading will change when the next reading is obtained. Accordingly, I see no possibility of confusion in using the instrument. Alternatively, by throwing a switch, a gong inside the chassis is connected that rings if, and only if, a new reading is obtained.

Vidicon for Film Pickup

By R. G. NEUHAUSER

This paper discusses the use of a vidicon camera tube for film pickup and describes special operating techniques for obtaining best performance. The operating principles of the vidicon are reviewed briefly and performance characteristics are given. Basic features desired for satisfactory reproduction of film on television are discussed, including high signal-to-noise ratio, "built-in" gamma of the proper magnitude, accurate black-level reproduction, excellent resolution, and freedom from spurious signals.

One might well wonder how a tube as small as the vidicon[1] can be made to produce a picture from film pickup equal or even superior to that produced by a broadcast-quality image orthicon or iconoscope. In view of the high picture quality needed for broadcast work, a pessimistic appraisal of the vidicon's performance would be justified — if the tube were operated in a conventional manner. However, by recognizing and applying some of the basic characteristics of the vidicon, and by the use of two special operating techniques, this small and relatively simple tube can be made to outperform present film-reproducing types, not only from the standpoint of picture quality, but in simplicity of associated equipment and operation.

The tube to be described in this paper is the recently introduced RCA-6326 film-camera vidicon. The useful performance characteristics of the RCA-6326 and the special operating techniques developed for its application to broadcast film pickup will be considered in detail. First, however, the operating principles of the vidicon will be reviewed to show how the signal is generated and to point out how these operating principles affect the performance of the tube in film-pickup systems.

Vidicon Construction

Figure 1 shows a cross section of the RCA-6326 vidicon and its associated components. On the inside of the faceplate are a signal electrode and a photoconductive layer. The signal electrode is a transparent, electrically conductive coating. External connection to the signal electrode is made through the flanged metal ring that forms the intermediate seal between the faceplate and the bulb wall. Deposited directly on this signal electrode is the photoconductive layer. This layer is a rather good insulator in the dark and has the

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Presented on October 7, 1953, at the Society's Convention at New York by R. G. Neuhauser, Radio Corporation of America, Tube Dept., Lancaster, Pa.
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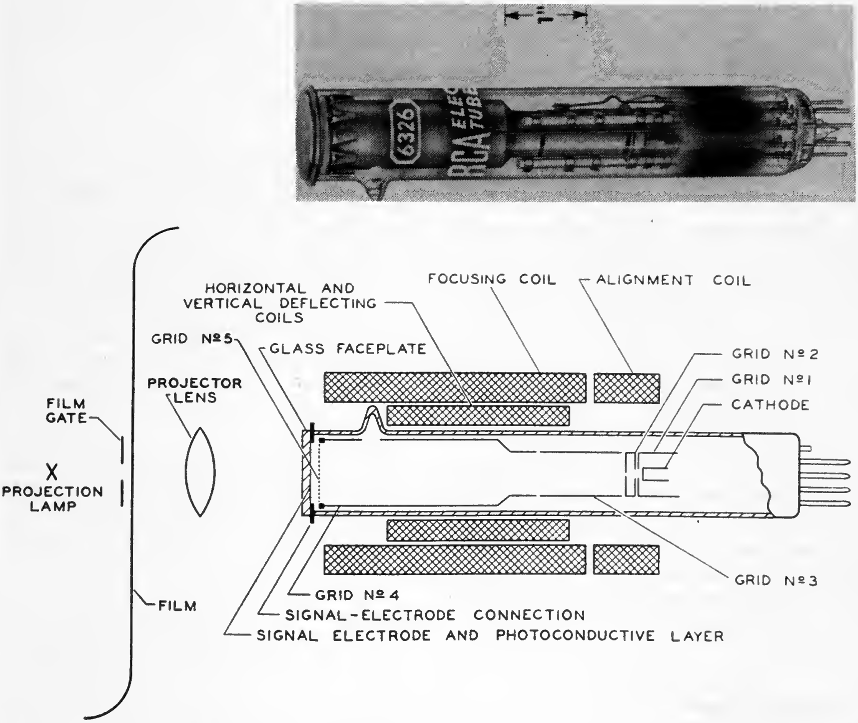

Fig. 1. Above: the RCA-6326 vidicon for film-pickup applications. Below: a cross section of the 6326 vidicon and its associated components.

characteristic of decreasing in resistivity when illuminated.

Directly behind the photoconductive layer is a fine-mesh screen (grid No. 5), which maintains a uniform decelerating field for the scanning beam supplied by the electron gun near the base of the tube. Behind grid No. 5 and connected to its periphery is a cylindrical electrode (grid No. 4). The scanning electron beam is brought to a sharp focus on the gun side of the photoconductive layer by the axial magnetic field of the external focusing coil and the electrostatic fields of grid No. 4 and grid No. 5, in much the same manner as in the image orthicon, but with only one loop of focus. Grid No. 3 is a separate electrode introduced for the purpose of applying a "dynamic focusing" voltage, if desired, to compensate for a slight degradation of focus in the corners of the picture. If "dynamic focusing" is not required, grid No. 3 is connected externally to grids No. 4 and No. 5. Scanning is accomplished by magnetic deflecting coils that are placed directly adjacent to the tube and inside the focusing coil. The alignment coil located at the rear of the focusing coil is necessary to align the electron beam with respect to the magnetic focusing field.

Vidicon Operation

Figure 2 illustrates the manner in which the vidicon generates a video signal from the optical image. The tube uses the same principle of low-velocity scanning as the image orthicon.

In this method of operation a small positive potential is applied to the signal electrode. The scanning beam lands on the surface of the photoconductive layer at vertical incidence and with nearly zero velocity, and drives the surface under the beam down to the potential of the thermionic cathode of the electron gun. The signal-electrode assembly and photoconductive layer form slightly leaky capacitors across which the signal-electrode voltage is impressed. The light from the scene to be televised is focused on the plane of the photoconductive surface and lowers its resistivity at each point in proportion to the light intensity at that point. In the interval between successive scans of any one picture element, each point on the beam side of the photosurface will charge up toward the signal-electrode potential through the leakage path set up by this change in conductivity. The photoconductive surface is so thin with respect to the picture-element size that there is no appreciable lateral leakage of this charge. Therefore, in the interval between scans, a charge pattern that corresponds to the illumination at each point is built up on the beam side of the photoconductive layer. The scanning beam deposits a sufficient number of electrons on this surface to drive the surface back down to cathode potential. A corresponding number of electrons flows out of the signal electrode and develops a video signal across the load resistor. The signal voltage across this resistor is coupled to the video preamplifier.

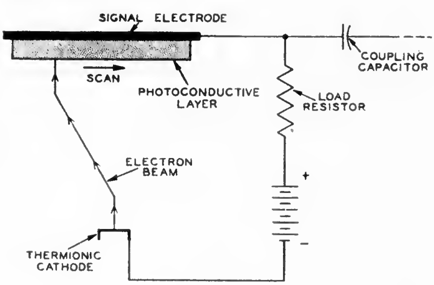

Fig. 2. Diagram of the vidicon principle. Illumination of the signal electrode by the projected film image produces a corresponding pattern of positive charges on the beam side of the photoconductive layer. These charges are reduced to cathode potential on each vertical sweep by electrons collected from the scanning beam. The resulting variations in signal-electrode constitute the video signal. No secondary-emission phenomena are involved due to the fact that the beam lands on the photosurface at practically zero velocity.

The following is a description of the performance characteristics of the 6326 vidicon and the significance of these characteristics in film-pickup applications.

Resolution

Resolution is one of the most important items to be considered when determining the usefulness of a camera tube for television broadcast work. In order to adhere to television terminology, we will refer to the resolving characteristics of the vidicon in terms of television line numbers and the horizontal amplitude response at a given line number. The horizontal amplitude response will be defined as the peak-to-peak signal response to a square-wave test pattern.

In determining the merit of any pickup device it is not sufficient merely to determine its limiting resolution, although in general, the device that has the highest value of limiting resolution will produce the sharpest picture. The film-pickup vidicon, if properly operated, will invariably show a limiting resolution in excess of 700 lines. However, limiting resolution alone has relatively little significance as a yardstick for evaluating the performance of the vidicon in a film-pickup system because the additional picture information available at the 700-lines point represents as

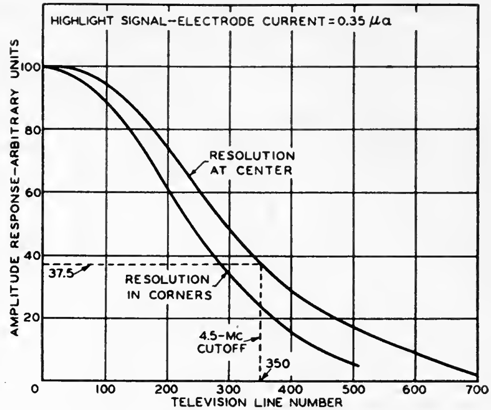

Fig. 3. Amplitude response (horizontal resolution) of the 6326 vidicon as a function of television line number. The slight loss in corner response can be corrected by the application of a "dynamic focusing" voltage to grid No. 3, as described in the text.

little as 2% of the total peak signal. The important characteristic of the vidicon is its amplitude response, which is shown in Fig. 3. A significant point on the curve is that for 350 lines, corresponding to the 4.5-mc cutoff frequency of the television broadcast video signal. The amplitude response at this point is 37.5% of the black-to-white signal at lower line numbers. This figure represents the resolution at the center of the tube. There is some degradation of the focus, and consequently of the resolution as the measurements are taken toward the corners of the raster. The corner response of the tube is also shown in Fig. 3.

Unlike the image orthicon or the iconoscope, the resolution of the vidicon is not affected by anything other than the dimensions and shape of the scanning beam itself. Since this is the case, high beam currents, which widen the spread of the beam considerably, will reduce the resolving capability. The measurements of amplitude response represented by Fig. 3 were taken with what is considered a desirable maximum-highlight signal-electrode current between 0.3 and 0.4 μa. An attempt to obtain greater highlight-signal output would require an increase in beam current and rapidly reduce the amplitude response of the tube.

Signal-to-Noise Ratio

The high signal-to-noise ratio of the vidicon video signal is perhaps its next most significant feature, because its high value allows the application of techniques that produce a picture of superior quality. Even when limited to between 0.3 and 0.4 μa, as previously noted, the highlight signal-electrode current of the film-pickup vidicon is approximately three times the peak signal available from the iconoscope generally used for film-pickup work. The visual equivalent signal-to-noise ratio* of the signal developed by the vidicon has been measured as 300 to 1. This figure, however, depends on the type of preamplifier used, since the vidicon itself contributes no appreciable noise to the video signal. The preamplifier recommended for this tube is a cascode type employing low-noise, high-transconductance triodes, similar to the preamplifiers used with iconoscope equipment. This feature of low noise in the video signal is of the utmost importance because it permits aperture correction to be used to best advantage.

Aperture Correction

The use of aperture correction is one of the special operating techniques

* Defined in the Appendix.

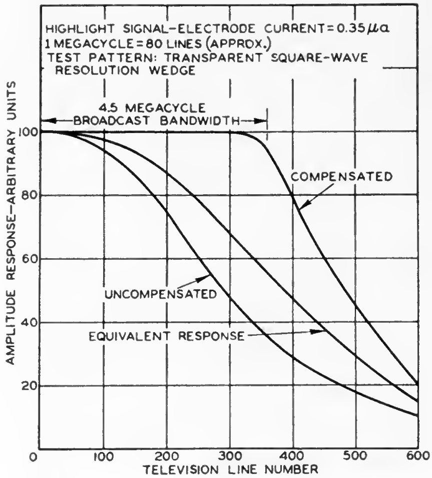

Fig. 4. Improved horizontal resolution (compensated curve) obtained by applying aperture correction to the output of the 6326 vidicon. The curve labeled "Equivalent Response" represents the geometric mean of the horizontal and vertical resolutions after aperture correction.

mentioned previously which enable the vidicon to produce superior performance. Aperture correction is the process of compensating for the drop-off in amplitude response shown in Fig. 3. Correction for this drop-off is accomplished by boosting the high-frequency response of the video amplifier in such a manner that the amplitude response curve is linear up to some predetermined cutoff frequency and compensating for the phase shift introduced in the frequency-response boosting process.[2] The vidicon is the first camera tube to develop a high enough signal-to-noise ratio to allow effective use of aperture correction. The application of aperture correction does not increase the *limiting resolution* of the vidicon, but it does make it possible to boost the *horizontal resolution* to 100% over the entire transmitted bandwidth as shown in Fig. 4.

The role which the high signal-to-noise ratio of the vidicon signal plays in aperture correction is as follows: The noise energy in the signal from the vidicon camera is contributed principally by the first amplifier stage. This type of noise is proportional to frequency, with the result that nearly all the noise energy in the video signal is concentrated in the higher frequencies. Boosting the signal information at the higher frequencies does not increase the overall signal amplitude, but it does boost the noise, with the result that the signal-to-noise ratio decreases almost directly as the amount of boost increases. A maximum boost of approximately 3 to 1 at the 350-lines point will reduce the signal-to-noise ratio of the picture to approximately 100 to 1, which is still a very satisfactory value.

It should be noted that this type of aperture correction does not boost the vertical resolution of the vidicon tube. The resulting equivalent amplitude response of the vidicon tube output signal is therefore a combination of the vertical and the horizontal amplitude responses. The resulting equivalent response is shown in Fig. 4. This curve is the square root of the product of the uncompensated and the compensated curves, and represents the overall performance of the tube with aperture correction of 3 to 1 at the cutoff frequency of 4.5 mc. The resulting signal-to-noise ratio is still higher than that of any camera tube or film-pickup system in current use.

Signal-Electrode Voltage

We have seen how the high signal-to-noise ratio of the vidicon can be used to improve its resolving capabilities. The second operating technique which clears up the remaining possible objections to the vidicon as a film-camera tube is the use of a signal-electrode voltage considerably lower than the value recommended for maximum sensitivity.

The use of reduced values of signal-electrode voltage for the vidicon improves its performance in two ways. The first and most pronounced improvement is a reduction in dark current. It will be remembered that the photoconductive layer is a rather good insulator in the dark. However, there is always some current flow through the material even in total darkness. A uniform dark current would not be objectionable but variations in the dark current over the useful area of the photoconductive layer are highly undesirable. This dark-current variation, if too prominent, will be exhibited as a flare signal, not unlike the signal from an iconoscope in the dark. It is logical to assume that if the average value of the dark current is reduced, the amplitudes of variations of the dark current will be reduced. Operation of the signal electrode at lower than normal voltage reduces the dark current to a very small value and, as a result, the dark-current flare in the picture is reduced to an imperceptible level. The sensitivity of the photosurface also decreases with this reduction in signal-electrode voltage, although not as rapidly as the dark current. This is illustrated by Fig. 5, which shows the ratio of signal current to dark current at various signal-electrode voltages, under constant illumination. However, for film-pickup applications this loss of sensitivity is a minor problem, since the vidicon has very high inherent sensitivity and the illumination needed for its small photosurface area is low.

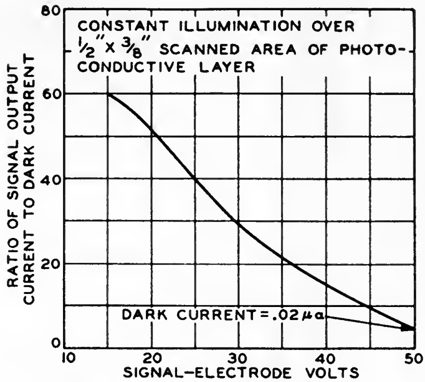

Fig. 5. Ratio of signal-output current to dark current in the 6326 vidicon at various signal-electrode voltages.

Signal Lag

Reduction of the applied signal-electrode voltage improved the performance of the vidicon in still another manner. One of the characteristics of the photoconductive surface used in the vidicon is a lag in its response to changing illumination. This produces a slight smearing of moving objects in normal operation. However, a reduction of the applied signal-electrode voltage and the resulting necessary increase in light on the photosurface considerably reduces the lag of the vidicon signal. The yardstick that has been adopted to measure or rate the lag is the amount of residual signal developed by the tube after 1/20 sec in the dark, which is slightly longer than the time necessary to discharge a complete frame. Figure 6 shows the lag of the vidicon signal at various signal-electrode voltages. It can be seen from this curve that the lag drops almost directly with the signal-electrode voltage. When operated at 25 v (one-half normal signal-electrode voltage), the residual signal after 1/20 sec is down to only slightly more than 10%, or less than half its normal value. By way of comparison, this is very close to the lag characteristic of an image orthicon operated at full storage. At this operating point, the lag of the signal produced by the vidicon is entirely unobjectionable in film reproduction.

Vidicon Gamma

The vidicon has several other very desirable characteristics that present no problems and require no special operating techniques. Perhaps the most important of these is its light-transfer characteristic.

If the light-transfer characteristic of a transducer such as a camera tube

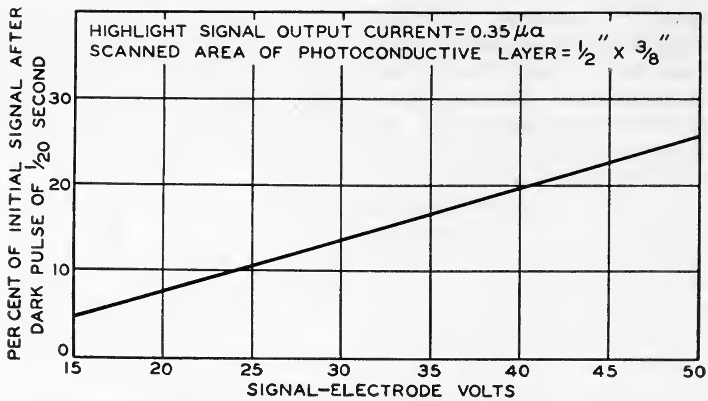

Fig. 6. Relative "lag" of the vidicon signal as a function of signal-electrode voltage.

follows closely a simple power law, we can refer to the slope of the transfer characteristic on a *log-lot plot* as the "gamma" of the device. The curves of Fig. 7 show that the gamma of the vidicon is essentially constant at 0.65 over the entire range of signal-electrode voltages given. This is almost exactly the desired gamma characteristic needed to match positive motion-picture film to a kinescope transfer characteristic. The overall transfer characteristic of such a system is slightly above unity gamma, which corresponds closely to current television-studio practice.

The photoconductive surface of a vidicon produces a very accurate and precise reproduction of a picture. Unlike other camera tubes it is not troubled by edging effects, electron redistribution, or flare, nor does the vidicon picture show any grain structure due to the

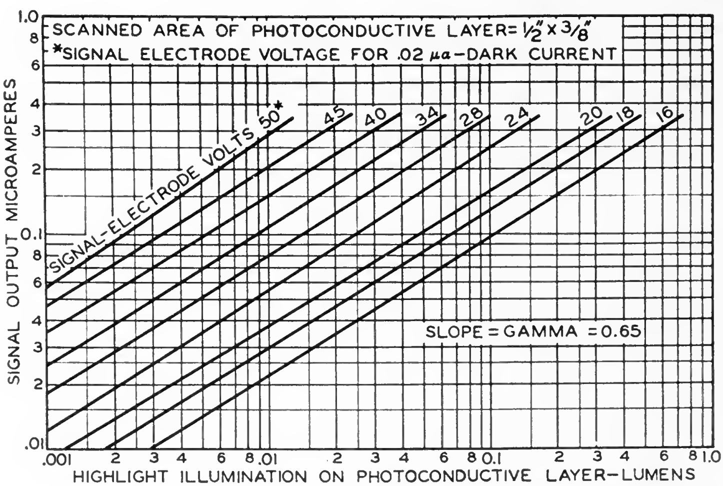

Fig. 7. Transfer characteristics of the 6326 vidicon at various signal-electrode voltages.

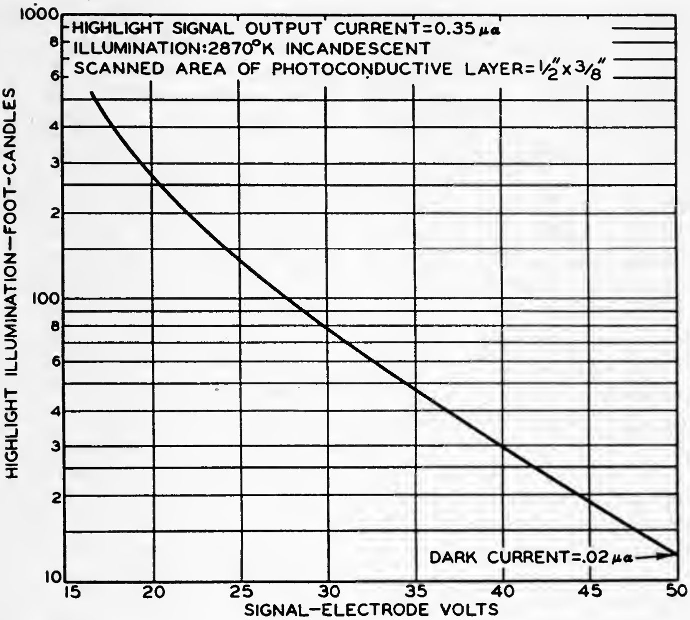

Fig. 8. Illumination requirements of the vidicon photosurface for a highlight-signal current of 0.35 μa.

fact that the photoconductive layer has a continuous surface. The constant gamma of the surface acts to reproduce each portion of the scene in its true tone values regardless of the illumination of adjacent areas or the overall illumination level. For this reason, the camera needs no white- or black-stretching circuits to produce a picture with accurate tone rendition. The gamma of 0.65 also allows the tube to generate a picture with a very high contrast range. A dynamic contrast range of 200 to 1 can be reproduced.

Black Level

Another desirable characteristic of the vidicon is its ability to furnish accurate black-level information in the video signal. With operation at low signal-electrode voltages, true blacks in the scene represent essentially zero current from the signal electrode. The signal during the scanning retrace also represents zero output current, since the scanning beam is prevented from landing during this time by the application of a blanking pulse to the electron gun. Blanking is accomplished either by applying a negative blanking pulse to the control grid of sufficient amplitude to cut the beam off completely or by the application of a positive pulse to the cathode. The positive pulse applied to the cathode need only be of sufficient amplitude to prevent the beam from landing on the photoconductive surface which has been driven to zero potential during the scanning interval. The signal level obtained during the retrace is used by the camera clamp circuits to set the black level of the video signal (sometimes called the "d-c component").

Light Requirements

The curve of Fig. 8 indicates the order of magnitude of illumination required on the photosurface to produce the recommended 0.35-μa value of highlight-signal current. It shows that the light required varies almost inversely with the cube of the signal-electrode voltage. In terms of foot-candles these figures may seem rather high, but actually only $\frac{3}{8}$ lm is needed to produce approximately 250 ft-c of illumination on the photosurface because the useful photo-area of the vidicon is only 0.875 sq in. ($\frac{1}{2} \times \frac{3}{8}$ in.).

Experience in operating the new vidicon in film cameras has shown that the optimum value of light on the photosurface is an average illumination of about 250 ft-c. Since there is some difference in sensitivity between individual film-pickup vidicons operated at a given signal-electrode voltage, the fixed parameter of a system will be the light level used, with the signal-electrode voltage adjusted to produce the proper output-signal level. The signal-electrode operating potential at this point will lie between 15 and 25 v, which is slightly less than half the voltage that would be used if maximum sensitivity were the only requirement.

Other Characteristics

The spectral sensitivity of the photoconductive layer used in the RCA-6326 vidicon is essentially panchromatic. It follows closely the spectral response of the image orthicon, having its lowest sensitivity in the red regions and practically no infrared response. This makes the vidicon highly suitable for the reproduction of color film on a monochrome system. The low infrared response of the tube makes an infrared filter in the optical system unnecessary from this standpoint, although such a filter may be required to reduce heating of the photoconductive layer at high illumination levels. Image storage on the vidicon presents no problem at all for motion-picture work. The storage characteristics are excellent. The length of time that an image can be stored on the photosurface without loss of amplitude or resolution is at least several seconds.

The vidicon can operate with any television film projector which has a 3–2 "pulldown ratio" or light-application rate. (In this type of projector the standard film speed of 24 frames/sec is converted to the 60-field/sec rate required for television by the use of a special shutter or pulsed light source which project five images of equal duration over each interval of 1/12 sec. The pulldown mechanism or drive holds successive frames of the film in the light gate for unequal lengths of time, so that the first frame of each pair is illuminated by three light pulses and the second by two.) In addition to this, one attractive feature of the vidicon is its ability to suppress the effect of the light-application bar of the film projector. If the light-application time is in the order of 30% of the active scanning time for a single television field, the light-application bar will be entirely unnoticeable. This is a very desirable characteristic because the projector meeting this requirement need not be synchronized with the field repetition rate of the television signal when used with the vidicon film camera. The tube will not operate satisfactorily in a system that does not have a projector with a 3–2 pulldown ratio or light-application rate because of the low-frequency flicker resulting from variations in the illumination of successive frames.

Exhaustive data on the life of the film-pickup vidicon have not been accumulated at this time due to the fact that the tube has only recently been made available for commercial use. However, indications are that it will be possible to obtain life in excess of 1000 hours in film-camera operation.

Conclusion

The behavior of the RCA-6326 film-pickup vidicon shows that this tube has all the basic performance characteristics desired for television broadcast use. Its outstanding features are high signal-to-noise ratio, "built-in" gamma of the proper magnitude, accurate black-level reproduction, excellent resolution, and freedom from spurious signals. The tube is also outstanding in its ease of operation and usefulness for nonsynchronous operation. It is felt that the new vidicon provides the best solution to date for the problem of film reproduction on television.

Acknowledgments

Acknowledgments are due to Robert B. Toppmeyer and F. David Marschka of the RCA Tube Dept., Lancaster, Pa., for assisting in the evaluation of the performance and quality characteristics of the vidicon for this application; and to B. H. Vine, also of the RCA Tube Dept., who did most of the basic design work on the tube and suggested a number of the operating procedures. H. N. Kozanowski and E. M. Gore of the RCA Engineering Products Dept., Camden, N.J., have also contributed much valuable information based on their work in developing a film-camera chain for the 6326 vidicon.

APPENDIX

Horizontal Amplitude Response: In this paper this term represents the measured peak-to-peak signal developed from a square-wave test pattern resolution wedge. This type of test is used more than any other for evaluating the resolving capabilities of a camera tube.

Equivalent Amplitude Response: This is the geometric mean of the horizontal resolution and the vertical resolution (both expressed in numbers of picture lines). It is expressed as $R_{eq} = \sqrt{R_v \times R_h}$ where R_v and R_h are the vertical and horizontal resolutions, respectively.

Signal-to-Noise Ratio: The term "visual equivalent signal-to-noise ratio" has been coined for this presentation. Since the vidicon signal is applied to a peaked amplifier, the noise of the camera video signal is concentrated at the high end of the transmitted band. This high-frequency noise is not as apparent to the eye as the lower-frequency noise components. As a result, for a 4.5-mc bandwidth the peak signal-to-rms noise ratio can be multiplied by a factor of approximately three to obtain the visual equivalent signal-to-noise ratio.[2] This is not true, however, of the image orthicon, which produces so-called "flat noise" having equal energy distribution throughout the bandwidth.

Gamma: This property of the transfer characteristic of a transducer such as a camera tube is obtained from the equation

$$I_s = E_i^{\gamma}$$

where I_s is the signal output,
E_i is the incident illumination, and
γ, or gamma, is the exponent.

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Discussion

James H. Ramsay (Philco Corp.): Is there another vidicon tube different from this one?

Mr. Neuhauser: There is a vidicon tube that was developed for the industrial market. That is the 6198, from which this one, the 6326, has actually evolved. The 6326 has a different gun structure and it is processed differently.

Mr. Ramsay: Could you go into much detail on the differences between the two?

Mr. Neuhauser: The differences are mostly in the gun structure and in the care and testing and processing, as well as in the quality limits.

Mr. Ramsay: The previous one, the 6198, did not have the dynamic focusing on it?

Mr. Neuhauser: That's correct. There was no dynamic-focusing electrode in the 6198. There is in this tube.

Mr. Ramsay: Also, could you explain what causes the good signal-to-noise ratio of this tube?

Mr. Neuhauser: The good signal-to-noise ratio is produced merely by the fact that you can get a high signal out of the tube. It produces about three to four times the signal that you get out of an iconoscope operated at 0.1-μa beam current, which is the value we recommend for the iconoscope.

Mr. Ramsay: Would not the signal-to-noise ratio of the iconoscope be equally as good if operated at the same illumination as is recommended for the vidicon?

Mr. Neuhauser: Not unless the beam current of the iconoscope were increased above the recommended value of 0.1 μa. Such an increase in beam current unfortunately produces uncontrollable flare or background variations as the result of excess secondary electrons falling back on the mosaic of the iconoscope.

Frank N. Gillette (General Precision Laboratory): You mentioned that the vidicon performed recently with shutter impulses of as little as 30% illumination duty cycle. Other workers in that field have reported the necessity of a taper on the rise and fall of the light beam when the duty cycle is as low as 30%. Do you confirm that result?

Mr. Neuhauser: I have a projector that has about a 25% application time square application pulse and I have not been aware of any application bar. As viewing gets more critical you may find that there has to be a tapered-light application. At present I would say it does not require a tapered shutter or a graded shutter.

Mr. Ramsay: You gave a figure on the number of seconds for storage time on this tube. Would that figure also hold for the 6198?

Mr. Neuhauser: I think it would, yes.

Mr. Ramsay: And that is storage time for an unscanned tube?

Mr. Neuhauser: Yes.

Vidicon Film-Reproduction Cameras

By HENRY N. KOZANOWSKI

Analysis and experience show that an ideal device for television film reproduction should have high resolution, excellent signal-to-noise ratio, wide contrast range, a stable gamma characteristic with a slope of 0.6 and good black-level control. It should operate with standard television projectors. Our work during the past two years has convinced us that the vidicon camera comes closest to this ideal. In addition to the characteristics already mentioned, the vidicon camera can be operated nonsynchronously, making it possible to provide local film inserts in network programming. The sensitivity for film operation is approximately three times greater than with the iconoscope, providing a large increase in projector lamp life. The simplicity and stability of a vidicon camera system make it very attractive for "unattended" operation with a minimum of adjustment and attention.

A particular form of vidicon film camera with its deflection, video and control circuits is described and illustrated. The problems and possible solutions of optical and electrical multiplexing for typical television broadcast operation are discussed. A broadcasting requirement for the reproduction of transparencies, opaques and other more specialized opaque presentations can be filled by equipment which is now in a product-development phase. We believe that, with the developments now available, the television broadcaster can provide picture quality in this field comparable with the best live pickup performance with equipment requiring only nominal attention and skill.

SINCE THE earliest days of television, both in its experimental phases and in commercial television broadcasting, the problem of reproducing motion-picture film has received concentrated and continued attention. Motion-picture film originally offered a wide choice of readily available program material as compared to the production of live-studio shows which require more elaborate facilities, long rehearsal time and considerably greater expense. With the development of better studio pickup cameras, such as those based on the image-orthicon tube, it became possible to produce high-quality studio programs

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with relatively modest lighting requirements. Under these conditions, it was apparent that improvements were required in the film system to bring it up to the new standards of studio quality. The iconoscope camera, which has been almost universally used for film reproduction, was re-examined thoroughly and many improvements were made in circuits and operating techniques.[1] These improvements have resulted in a substantial gain in picture quality and have been widely introduced into current film-reproducing equipment in television broadcasting stations. With high-quality film and careful operating techniques, the pictures compare favorably with those which originate in studios.

However, within the last few years, there has been a definite trend in the direction of recording certain programs directly on film for reasons of smoother performance, possibilities of editing, less strain on actors and the increased versatility provided by the application of well-developed motion-picture techniques. Such a program is, therefore, no longer considered as a substitute for live-studio programs, but as a direct competitor. In this case, the ultimate goal is picture quality which will make it impossible for the home television viewer to know whether the program material is live or has been recorded on film. The same goal is called for in kinescope photography for delayed broadcast, program storage and distribution by network-affiliated stations. The formation of these new trends in television broadcasting spurred on an intensive program of evaluating many incompletely explored methods of film reproduction. Investigations showed that the vidicon pickup tube offers the greatest possibility for realizing these new objectives. Our work on the Vidicon Film Camera during the past two years has convinced us that it comes closest to meeting the requirements for an ideal film camera.

Performance Requirements for a Television Film Camera

Before describing the vidicon camera, it may be of interest to tabulate the main factors in any television reproducing system which are the criteria for good performance. These are:

A. Resolution or aperture response.
B. Available signal-to-noise ratio.
C. Possibility of aperture-response correction.
D. Gray-scale or transfer characteristic.
E. Film-reproduction range and film latitude.
F. Light-source requirements.
G. Effect of spurious signals or shading.
H. Black-level reference.
I. Nonsynchronous projector operation.
J. Possibilities for unattended operation.

The vidicon tube was invented at RCA Laboratories[2] and developed into a commercial product at the RCA Victor Tube Development Group at Lancaster.[3] The capabilities and potentialities of the vidicon for high-quality film reproduction were first clearly recognized and demonstrated by R. G. Neuhauser of Lancaster. A detailed discussion of the theory and operation of this tube under film reproduction conditions is given by Neuhauser in the preceding paper in this *Journal*.[4]

We can most effectively evaluate vidicon performance by referring to the previously mentioned factors and reporting observations and measurements on these characteristics.

A. Resolution: The 1-in. vidicon with a 0.62-in. picture diagonal ($\frac{3}{8} \times \frac{1}{2}$ in. picture) has a limiting television resolution of 800 lines in the center of the raster, with a measured response of 35% at 350 lines compared with zero line number as a base.

B. The signal-to-noise ratio, measured as peak-to-peak signal to rms noise can be as high as 300 to 1. It is determined mainly by the shot noise-characteristics of the input stage of the camera amplifier. High-performance, low-noise cascode amplifiers are used for this application.

C. The possibility of aperture response correction is particularly inviting with the vidicon because of the excellent signal-to-noise relation. For example, it is possible to raise the aperture response from 35% to 100% at 350 lines resolution by suitable techniques and still maintain a signal-to-noise ratio of 100 to 1. This improves horizontal resolution, but does not affect vertical resolution. Overall tests indicate that the process is definitely necessary for all pickup tubes, but can be used only where signal-to-noise performance is not sacrificed.

D. The gray-scale or transfer characteristic, which is inherent in the vidicon surface itself, has a log-log slope of 0.65 when signal output current is plotted against light on the photoconductive target. (This gamma is complementary to the kinescope transfer gamma characteristic, requiring no further correction in the video amplifiers.) A dynamic range of 150 to 1 or more in the usual gray-scale logarithmic test wedge can readily be demonstrated. With the iconoscope, 50 to 1 represents a value which can be attained only with special precautions. The slope is constant over a wide range of lighting and does not have the "rubbery" or variable gamma handicap of the iconoscope.

E. Film-reproduction range and latitude are wide, due both to the low gamma and to the constant character of the signal output – light input characteristic. Normal shifts in print density produce very little change in quality since these can be compensated by either a change of video gain or projector light output. The high signal-to-noise ratio initially available makes this possible.

F. Light source requirements under typical conditions, and using commercially available lenses, are of the order of 300 ft-c, average, measured at the film gate. Since practically all intermittent-type television motion-picture film projectors used with the iconoscope have an exposure shutter opening of approximately 7%, phased under blanking, this 300-ft-c average corresponds to about 4000-ft-c peak. Optimum vidicon results are obtained using approximately $\frac{1}{3}$ of the maximum light output available in standard television projectors designed for use with the iconoscope. Sensitivity is deliberately sacrificed for improved performance by the use of a low signal-electrode voltage. The decrease in light requirements nevertheless prolongs projector lamp life greatly.

G. Since the vidicon tube is essentially an orthicon or low-velocity device as far as the scanning process is concerned, there is inherently no spurious shading signal developed. This contrasts very favorably with the iconoscope where elaborate precautions in edge lighting and waveform cancellation are necessary to minimize a normally large spurious signal. In the vidicon, no electrical shading cancellation signals are required, thus resulting in equipment and operational simplifications. In early models of vidicons, there were problems of maintaining uniform sensitivity of the photoresistive signal-electrode, so there was unequal signal output at the edges as compared to the center of the raster. Improvements in production techniques have made such variations negligible.

By operating the vidicon signal-electrode at low voltages for motion-picture film use, the decreased dark current of the device and the improvement in lag and burn characteristics greatly outweigh the loss of light sensitivity. High light sensitivity is vital for direct pickup cameras, but is of only casual interest in motion-picture reproduction.

H. Black-level reference in the vidicon is clean-cut and definite since the output resistor signal voltage, even on a d-c basis, is a function only of light on the raster. Thus, the zero signal or black reference is obtained directly, merely by blanking the scanning beam during the horizontal return interval. Standard clamping techniques can thus be used for automatic d-c set or black-level control.

I. Nonsynchronous operation of the projector with respect to the synchronous generator is a desirable attribute of a film-reproduction chain. In smooth network operation, it is often necessary to insert commercials or local film material in station-break intervals. Present techniques call for: fading to black; dropping network synchronizing signal; switching to local synchronous generator, which is locked to and properly phased with the local a-c power supply; and operating the iconoscope film chain conventionally. All of this is essential because of the necessity for exposing the iconoscope during the vertical blanking interval. Misphasing or nonsynchronous operation produces the well-known iconoscope application bar whose amplitude may be 10 to 20 times the useful normal video signal. Several synchronous projector drives, providing driving power with frequency controlled by the synchronous generator, have met with some success in solving this problem. By comparison, the vidicon behaves beautifully under nonsynchronous projector conditions. With a projector light exposure pulse of 7% of vertical field time, standard iconoscope exposure conditions, the "application pulse" signal is perceptible to a critical viewer, but is not particularly annoying. With longer application times, 30 to 65%, available with present 3–2 television projectors, such as the RCA TP-6A, the transition from "Light On" to "Light Off" is not detectable even to the most critical viewer. Long-application time also cuts down the peak illumination requirements. This means either smaller projector lamps or increase in projector lamp life by a factor of 10, or even more. Inserts in network program can thus be made merely by operating the projector from the local power supply with the local synchronous generator tied to network through a Genlock or similar device. The importance of such a feature will increase as network-to-local operation techniques are refined.

J. The "unattended operation" possibilities of the vidicon camera appear unusually attractive. Tests with a wide range of film material have shown that it is practically unnecessary to ride video gain. Black-level control is completely automatic, and there are no shading knobs provided or required. The controls are inherently stable and simple. In principle, the only two variables which require adjustment are wall voltage, which determines electrical scanning-beam focus and, therefore, picture resolution; and beam bias, controlling the number of electrons available for discharging the target. Even this last adjustment is noncritical in that the top beam-current requirement can easily be set by simple operational procedures, and any excess produces only secondary deteriorations in resolution due to increased scanning-spot size at lower grid biases. The vidicon is far less critical to set up and operate than the image-orthicon tube. That this is so follows from the fact that in the vidicon the useful video signal is generated only by the electrons flowing through the photoresistive signal electrode, while in the image orthicon, the video signal is obtained from the "return" electrons of the scanning beam, making it essential to adjust beam current very carefully to maintain "percentage modulation" at a high value.

Extensive tests show that the inherent stability of the vidicon tube and camera circuits is sufficiently high to make "unattended operation," using only a bare minimum of monitoring and adjustments, a practical reality. This is believed to be of great importance to the television broadcaster.

This paper up to the present moment encroaches on the territory which is normally the province of the pickup-tube development engineer. However, tube and camera performance are so intimately related that it is practically impossible to draw a sharp dividing line between the two activities and still present an informative picture of developments and progress.

Features of Vidicon Camera Design

The vidicon camera system, which will now be described, is the third model resulting from information acquired in the advance development phases of the study.

The general philosophy of approach was based on the following goals:

1. The camera itself should be as small as possible so that it can be mounted directly on either a 16mm or 35mm projector or integrated into an optical multiplexing system.
2. The control circuits should be rack mounted for ease of maintenance and performance check. This has obvious advantages over locating them in a chassis set in a desk-type operating console, with poor accessibility.
3. The control panel containing the various operating and setup controls should be capable of location remote from the rack, should contain no electron tubes, and its connecting cables should not carry any signals except variable d-c voltages.

Following this approach, the camera contains only the vidicon tube, focus and deflection coils, a high-performance cascode amplifier, a low-impedance video output stage and a vidicon blanking amplifier.

Since the deflection requirements are relatively modest, horizontal deflection is supplied to the camera from a rack-mounted deflection amplifier through a coaxial conductor in the standard camera cable. A constant resistance termination is used, with the horizontal deflection coils as one of the termination elements. Suitable circuits are used for protection of the vidicon tube in the event of scanning failure. Regulated focus field current and other required operating waveforms are supplied to the camera from the rack chassis by conventional methods.

Other elements of the rack chassis assembly perform such functions as high-peaking to compensate for the effect of vidicon input shunt capacity, aperture compensation,[5] final blanking, clamping, clipping and addition of synchronizing signals. A standard RMA signal of 1.0 v is produced across the usual 75-ohm coaxial distribution line.

Figure 1 is a block diagram of the essential portions of the system. A vidicon camera mounted directly on a TP-6A 16mm Projector is shown in Fig. 2, and Fig. 3 is a detailed view of the vidicon camera.

Figure 4 shows the general appearance of the junction chassis; the focus, deflection, and protection assembly; the final processing amplifier; and the control panel. In an actual operational installation, all of the units except the control panel are mounted in a standard broadcast-type rack and are interconnected by suitable plugs and cables. The control panel is usually installed horizontally below a master monitor for convenience in operation.

Television Film Projectors

It can be mentioned that the vidicon, because of its well-behaved storage characteristics, can be used with any projector, continuous or intermittent, with long- or short-application time, which has suitable television conversion features. These are implied in the requirement of translating 24 film frames/sec into 30 complete television

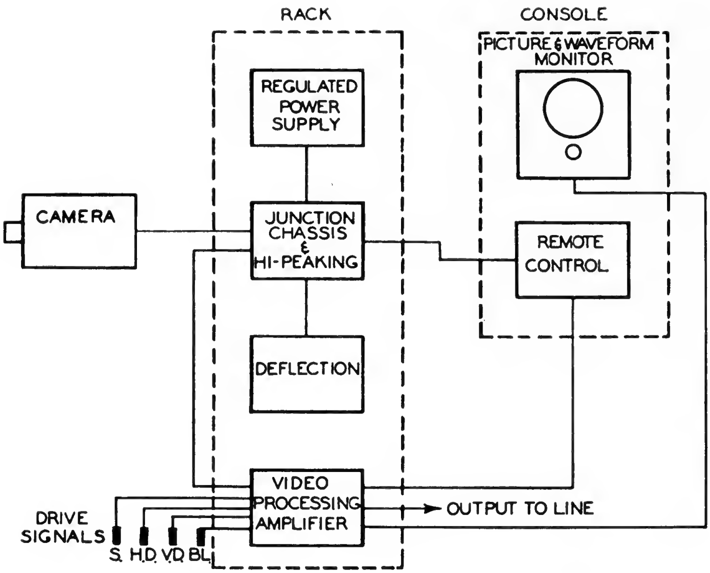

Fig. 1. Block diagram — vidicon film camera system.

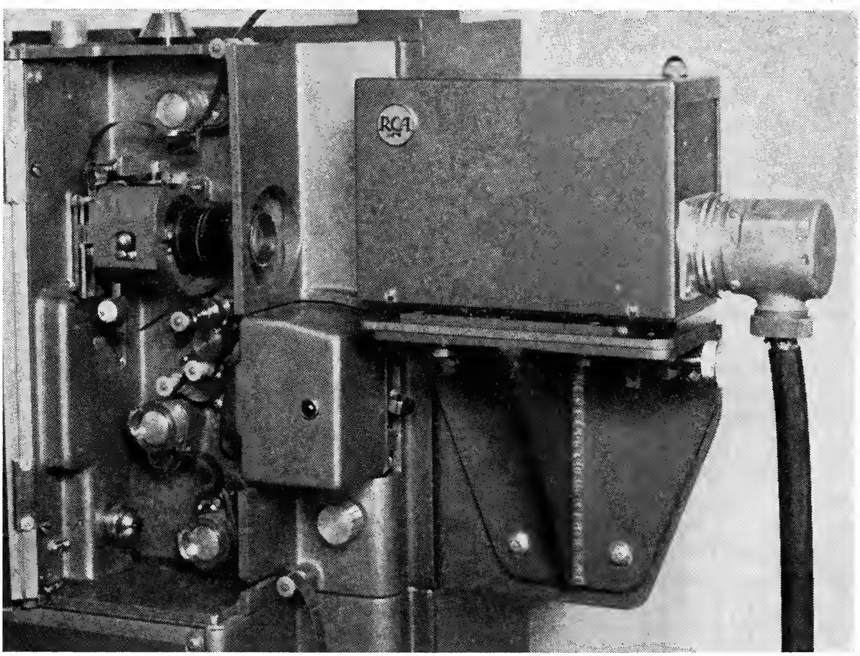

Fig. 2. Vidicon camera mounted on TP-6A 16mm Film Projector.

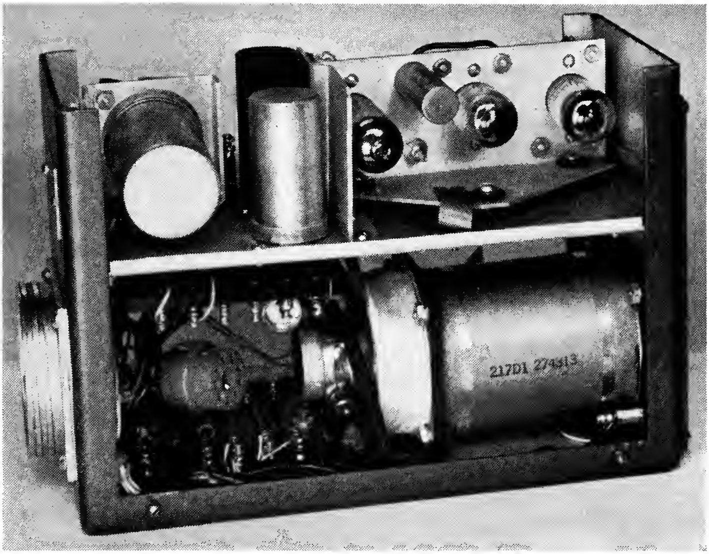

Fig. 3. Details of the vidicon camera.

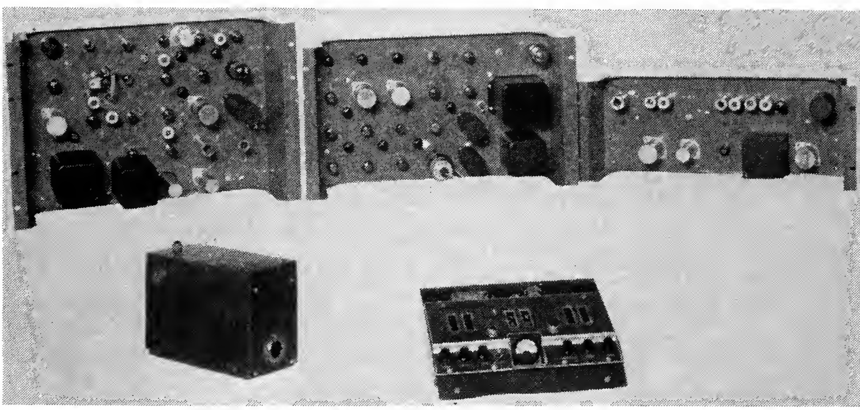

Fig. 4. Camera, rack chassis and control panel.

rasters in the same interval. Thus, there is a wide field of choice and the possibility of continuing to use, with complete satisfaction, the large number of projectors which are already in commercial broadcast operation.

The Multiplexing Problem

One of the major problems of the television broadcaster is to provide smoothness or continuity in programming without paying a high price in complexity of duplicated equipment, operating procedures and space requirements. This is particularly true with the smaller broadcasting stations which often show a film feature, insert 15-sec film spot commercials, slide or opaque commercials, then station identifications, and go back to film. They have become thoroughly accustomed to going through such split-second tactics using only a single iconoscope film camera and multiplexing the information from two projectors, a Telop for opaques, and one or more transparency projectors, onto the iconoscope mosaic in the required sequence by means of mirror and douser techniques. They naturally expect that any improved device such as the vidicon camera will give them the same, or even more, operational flexibility.

With the iconoscope, the multiplexing problem is quite easily solved, since the diagonal of the photosensitive mosaic is 5 in. and the projector lens throw for the required magnification from 16mm or 35mm film is about 50 in. This 50-in. working distance is utilized for suitable mirror and projector source locations so that any one of three or more projection devices can be selected at will for program continuity.

The vidicon, on the other hand, has a picture diagonal of slightly less than $\frac{5}{8}$ of an inch, giving practically a unity magnification ratio for 16mm film and a 2:1 demagnification for 35mm frames. This consequently gives a lens throw of the order of 7 to 10 in., which is far too small for conventional multiplexing techniques. This, however, works out very conveniently for mounting a camera directly on the projector and gives the possibility of electrically multiplexing the outputs as required by program needs. There seems to be a definite trend in this direction by network originating stations.

This technique does not solve the problem for the small broadcaster who cannot afford the increased equipment, personnel and floor space required. A method of multiplexing has been devised and tested which appears to provide an excellent answer. The basis for operation is the creation of a working distance for accommodation of the required multiple mirrors and projector sources. This is done by projecting a real image in space, whose diagonal is 5 in., and picking up this image with a lens on the vidicon camera itself. A suitable field lens in the 5-in. image plane is used to direct the peripheral rays into the vidicon lens aperture. This technique allows the use of standard high-quality 16mm motion-picture lenses which are available at reasonable cost.

A similar application of relay lens techniques has been used in the RCA color camera and has given very good results from the viewpoint of resolution and detail contrast.[6] A schematic diagram of the elements of this system is shown in Fig. 5. With a carefully designed optical multiplexing system, the degradations introduced in the television picture by the additional lens process are definitely of second order. If the camera is made as an integral part of the optical system, the effects of projector vibration on image quality are no different from those with the iconoscope and direct projection. These are quite small in commercial operation.

Such an optical multiplexer is now in the product-design phase and is arranged to handle two film projectors, 16mm or 35mm, an opaque projector, and a remotely controlled preloaded projector for 2 × 2 in. transparencies.

16mm and 35mm Film Material

The question of film quality for television reproduction has been the subject of much study. Even though it is realized that 16mm film has tremendous commercial advantages in first cost, projector cost, storage requirements, air express shipping charges, fire code restrictions, and many other factors, the fact still remains that the best 16mm prints are none too good for television. An equivalent limiting television resolution of over 400 lines with 16mm release prints is rare. This contributes nothing to overall quality. By comparison, 35mm prints on the average have much higher performance from the standpoint of resolution, gray

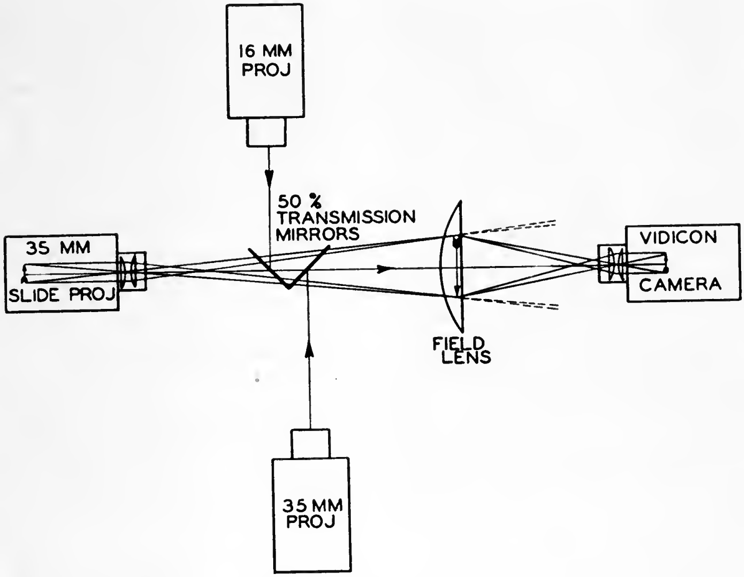

Fig. 5. Schematic diagram — optical multiplexer.

scale and grain. A great deal of the difference may well lie in the more careful control of exposure, step-printing and processing of 35mm film. It may be economically unsound to expend the same effort on production of 16mm film subjects. While there seems to be practically no likelihood of using 35mm film, except for network originations where the demands for high quality are extremely exacting, it is important to stress the fact that any technical improvements in 16mm film quality will be directly reflected in improved television picture quality.

A question often asked by broadcasters who have witnessed film reproduction with the vidicon camera is: "What are the results using the vidicon with poor-quality film?" The answer, unfortunately, is: "Poor." No television system, including the vidicon camera, can do very much to make film of poor technical quality look better on television than it looks on direct critical viewing. Perhaps a conservative way of expressing the same idea is to say that the system should introduce a minimum amount of deterioration in the translation of the optical information into a television picture signal.

Conclusions

Our study of the possibilities inherent in the use of the vidicon camera for high-quality reproduction of motion-picture film has been going on for about two years. During the last six months, the results have been observed by a wide range of critical television broadcasting observers, both in the laboratory and at the NARTB Convention at Los Angeles. The comments on reproduction fidelity, gray-scale reproduction, signal-to-noise ratio and operational stability have been extremely gratifying. We believe that the vidicon approach to motion-picture reproduction represents the most promising method of high-quality reproduction now available, and hope that its use in commercial broadcasting will continue to justify the enthusiasm which has been aroused during its development.

Acknowledgments

We acknowledge with pleasure the cooperation of R. G. Neuhauser, F. S. Veith and Dr. R. B. Janes, of RCA Lancaster, in the solution of many tube and circuit problems, and the help of Dr. O. H. Schade in providing a firm basis for evaluation of performance. The advance-development phase of the problem owes much to E. M. Gore and S. L. Bendell of RCA Victor, Camden. The commercial embodiment of the equipment is due to the efforts of N. L. Hobson and F. E. Cone of the Broadcast Equipment Section.

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Screen Brightness Committee Report

By W. W. LOZIER, Committee Chairman

THIS REPORT will review progress since the last formal report of the Committee presented to the Society at its October 1952 meeting.[1] It will also summarize the present status of various projects on the occasion of the completion of the writer's term of office as Chairman.

1. Subcommittee on Instruments and Procedures: This group under the chairmanship of F. J. Kolb, Jr., has prepared its report "Specifying and Measuring the Brightness of Motion Picture Screens," which was published in the October 1953 *Journal*.[2] This report gives an exceptionally thorough analysis of the requirements, specifications and methods of use for various types of meters ranging from the research-type meter, which will do a most complete job of measuring all phases of intensity of incident illumination and reflected brightness over all portions of the motion-picture theater, on down to the most limited type of meter which will determine only the total luminous output of the projector without giving any information as to how this light is distributed over the picture screen and to the motion-picture audience. Having completed its assignment, this Subcommittee has now been disbanded.

It is gratifying to the Committee to note that screen-brightness meters embodying many useful and desirable features have recently become commercially available.[3]

Submitted on December 29, 1953, by W. W. Lozier, National Carbon Company, Division of Union Carbide and Carbon Corp., Fostoria, Ohio.

2. Subcommittee on Projection Screens: New industry developments have been announced with such frequency over the past several months as to prevent this group from bringing its work to a conclusion. This group, originally set up to prepare standards of whiteness and brightness of motion-picture screens, will need to consider, in addition to the familiar matte-type screen, the other types of screens which have recently come into prominence.

3. Subcommittee on Illumination Practices: This group has likewise been unable to carry out its assignment due to pressure of other activities. Their task of preparation of recommended practices concerning distribution of illumination on motion-picture screens should be an important future committee activity.

4. *Subcommittee on Screen Photometry:* This group, recently formed under the chairmanship of Gerhard Lessman has been given the assignment of definition of terms and description of methods necessary for determination of the important photometric characteristics of screens, with special reference to the polarization properties so important to stereoscopic motion pictures. This group has been at work only a short time, but is expected to produce important results.

Revision of Screen-Brightness Standard: A revision of American Standard Screen Brightness for 35mm Motion Pictures, originated by the Committee, has recently been approved and issued as PH22.39-1953.[4]

Screen Brightness for 16mm Laboratory Review Rooms: The Screen Brightness Committee is assisting the Laboratory Practice Committee in the formulation of a standard for the brightness of the screens used for viewing 16mm film prints in the laboratory review rooms.

Symposium on Screen Brightness: The Committee sponsored a symposium of five papers presented at the Spring 1953 Convention of the Society in Los Angeles and later published as Part II of the August 1953 issue of the *Journal*.[5] These five papers covered such subjects as screen-brightness meters, carbon-arc projection systems, relation of screen brightness to picture quality and the effects of stray light.

Conclusion: Although much important and useful information has become available during the past few years, there remains a rich field of activity for the Committee during future years. In addition to the discovery and dissemination of new information, there remains the important task of translating existing knowledge into useful recommendations and standards to improve the quality of motion pictures.

References

1. W. W. Lozier, "Screen Brightness Committee Report," *Jour. SMPTE, 59:* 524–525, Dec. 1952.
2. F. J. Kolb, Jr., "Specifying and measuring the brightness of motion-picture screens," *Jour. SMPTE, 61:* 533–556, Oct. 1953.
3. Frank F. Crandell and Karl Freund, "New photoelectric brightness spot meter," *Jour. SMPTE, 61:* 215–222, Aug. 1953.
4. American Standard, Screen Brightness for 35mm Motion Pictures, PH22.39-1953, *Jour. SMPTE, 60:* 630, May 1953.
5. Symposium on Screen Brightness (5 papers), *Jour. SMPTE, 61:* 213–272, Aug. 1953.

The Committee

W. W. Lozier, *Chairman*

H. J. Benham	L. J. Patton
F. E. Carlson	O. W. Richards
M. H. Chamberlin	Leonard Satz
B. S. Conviser	Ben Schlanger
Philip Cowett	Allen Stimson
E. R. Geib	C. R. Underhill
L. D. Grignon	G. H. Walter
A. J. Hatch, Jr.	H. E. White
L. B. Isaac	A. T. Williams
W. F. Kelley	D. L. Williams
F. J. Kolb, Jr.	J. J. Zaro
Gerhard Lessman	

Reaffirmations of Standards — 1953

Listed below are 11 American Standards, approved by the appropriate ASA committees October 1, 1953, as Reaffirmations. The only change from the previous edition of each is in the PH designation. Included are the dates of prior *Journal* publication of the complete standards.

PH22.27-1947, Method of Determining Transmission Density of Motion-Picture Films (includes Z38.2.5-1946), Mar. 1948, p. 283.

PH22.37-1944, Raw Stock Cores for 35mm Motion-Picture Film, Sept. 1946, p. 262.

PH22.46-1946, 16mm Positive Aperture Dimensions and Image Size for Positive Prints Made From 35mm Negatives, Apr. 1946, p. 298.

PH22.47-1946, Negative Aperture Dimensions and Image Size for 16mm Duplicate Negatives Made from 35mm Positive Prints, Apr. 1946, p. 299.

PH22.60-1948, Theatre Sound Test Film for 35mm Motion-Picture Sound Reproducing Systems, Nov. 1948, p. 539.

PH22.62-1948, Sound Focusing Test Film for 35mm Motion-Picture Sound Reproducers (Laboratory Type), Nov. 1948, p. 541.

PH22.65-1948, Scanning-Beam Uniformity Test Film for 35mm Motion-Picture Sound Reproducers (Service Type), Nov. 1948, p. 542.

PH22.66-1948, Scanning-Beam Uniformity Test Film for 35mm Motion-Picture Sound Reproducers (Laboratory Type), Nov. 1948, pp. 543–544.

PH22.67-1948, 1000-Cycle Balancing Test Film for 35mm Motion-Picture Sound Reproducers, Nov. 1948, p. 545.

PH22.69-1948, Sound Records and Scanning Area of Double Width Push-Pull Sound Prints, Normal Centerline Type, Nov. 1948, p. 547.

PH22-70-1948, Sound Records and Scanning Area of Double Width Push-Pull Sound Prints, Offset Centerline Type, Nov. 1948, p. 548.

Six Proposed American Standards PH22.42, –.45, –.57, –.88, –.98 and –.99

Three proposed revisions of American Standards and three proposed new American Standards are published on the following pages for a 3-month period of trial and criticism. Comments should be sent to Henry Kogel, Staff Engineer, prior to May 15, 1954. If no adverse comments are received, the six standards will then be submitted to the ASA Sectional Committee PH22 for further processing as American Standards.

All six standards are a product of and have been approved by the Sound Committee under the chairmanship of John Hilliard. The initial work on the three proposed standards on magnetic sound was done by the Magnetic Recording Subcommittee under the chairmanship of Glenn Dimmick.

Revision of Z22.42-1946, Z22.45-1946 and Z22.57-1947 was undertaken for the purpose of modifying the section on identification. However, in the process of review, several additional changes primarily of an editorial nature were made.

In PH22.42, the title was simplified, a section added on film stock, section 2.1.1 eliminated and it's specification made a part of section 1, Scope.

In PH22.45, the title was simplified, section 2.2.1, Resistance to Shrinkage, was deleted and section 2.4 was modified to be in accordance with present practice.

In PH22.57, the title was simplified, a negative tolerance was added to the specification of density, section 2.3.1, Resistance to Shrinkage, was deleted and the sound-track edge was indicated as the guided edge.

PH22.88, Magnetic Sound Specifications for 8mm Motion-Picture Film, was published previously in the July 1951 *Journal* for trial and comment. Exceptions were taken to the location and dimensions of the magnetic coating. These differences have now been resolved and the specifications made consistent with the 16mm magnetic sound proposal now before the Sound Committee.

PH22.98, and PH22.99 are relatively recent proposals and have not been published previously. — *HK.*

Proposed American Standard

16mm Sound-Focusing Test Film

(Second Draft)

PH22.42

Revision of Z22.42-1946

1. Scope

1.1 This standard specifies a test film to be used for checking the focus of the scanning beam of 16mm sound motion-picture projectors.

Type A — 7000-cycle recording for manufacturing and precision adjustment of sound focusing;

Type B — 5000-cycle recording for quick field adjustment of sound focusing.

2. Test Film

2.1 The test film shall have an originally recorded variable-density sound track heavily overmodulated and developed to high contrast so that the resultant track is essentially a square-wave track.

2.2 The sound track shall have correct azimuth to within ± 5 min of arc.

3. Film Stock

3.1 The film stock used shall be of the low-shrinkage, safety type, cut and perforated in accordance with American Standard PH22.12-1953, Dimensions for 16mm Film, Perforated One Edge, or the latest revision thereof approved by the American Standards Association, Incorporated.

4. Identification

4.1 Each film of Type A shall be marked **SMPTE — ASA — PH22.42 — 7000-Cycle Focusing.** Each film of Type B shall be marked **SMPTE — ASA — PH22.42 — 5000-Cycle Focusing.** This marking shall be printed lengthwise in the picture area, the spacing between consecutive titles to be approximately 12 in.

5. Film Length

5.1 The film shall be supplied in 100-ft lengths.

NOTE: A test film in accordance with this standard is available from the Society of Motion Picture and Television Engineers.

NOT APPROVED

Proposed American Standard

16mm 400-Cycle Signal-Level Test Film

(Third Draft)

PH22.45

Revision of Z22.45-1946

1. Scope

1.1 This standard specifies a 400-cycle signal-level test film for use in testing 16mm sound motion-picture projection equipment.

2. Test Film

2.1 The test film shall have an originally recorded, direct-playback, positive variable-area sound recording at an amplitude of 0.0480 ± 0.0015 in. Each film shall be measured for amplitude and the measurements shall be made at a point approximately mid-length of the film and at points between 5 ft and 10 ft from each end.

2.2 The frequency of the recording shall be 400 ± 8 cycles per sec.

2.3 The density of the dark portion of the sound track shall be between 1.2 and 1.4. The density throughout the length of the film shall be as uniform as is consistent with the state of the art.

2.4 The combined base and fog density shall be 0.05 ± 0.01, measured as diffuse transmission density in accordance with American Standard Z38.2.5-1946, Diffuse Transmission Density, or the latest revision thereof approved by the American Standards Association, Incorporated.

2.5 The total harmonic distortion of the recording shall not exceed 5% and the fluctuation of the recorded level shall not exceed 2%.

2.6 Each film shall be run in a standard calibrated reproducer for the purpose of obtaining the level of recording; this level shall be compared with that of the standard control film and the difference shall be noted in the booklet furnished with each film.

3. Film Stock

3.1 The film stock used shall be of the low-shrinkage, safety type, cut and perforated in accordance with American Standard PH22.12-1953, Dimensions for 16mm Film, Perforated One Edge, or the latest revision thereof approved by the American Standards Association, Incorporated.

4. Identification

4.1 Each film shall be marked **SMPTE — ASA — PH22.45 — 400-Cycle Signal Level.** This marking shall be printed lengthwise in the picture area, the spacing between consecutive titles to be approximately 12 in.

5. Film Length

5.1 The film shall be supplied in 100-ft lengths.

NOTE: A test film in accordance with this standard is available from the Society of Motion Picture and Television Engineers.

NOT APPROVED

Proposed American Standard

16mm Buzz-Track Test Film

(Third Draft)

PH22.57

Revision of Z22.57-1947

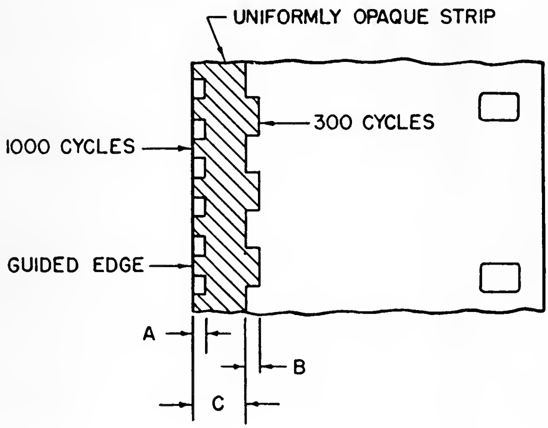
1. Scope

1.1 This standard specifies a buzz-track test film used for checking the position of the sound scanning beam in 16mm motion-picture sound reproducers.

2. Test Film

2.1 The test film shall have originally recorded 300-cycle and 1000-cycle signal tracks on either side of the central exposed strip as shown in the drawing.

2.2 The position of the tracks, weave in running film on the recorder included, shall be in accordance with the dimensions given in the table below:



Dimension	Inches	Millimeters
A	0.0200 + 0.0005 − 0.0000	0.510 + 0.012 − 0.000
B	0.018 ± 0.001	0.460 ± 0.025
C	0.0960 + 0.0000 − 0.0005	2.440 + 0.000 − 0.012

NOT APPROVED

2.3 The central exposed strip and the exposed portions of the two signal tracks shall have a density of $1.6^{+0.4}_{-0.0}$

3. Film Stock

3.1 The film stock used shall be of the low-shrinkage, safety type, cut and perforated in accordance with American Standard PH22.12-1953, Dimensions for 16mm Film, Perforated One Edge, or the latest revision thereof approved by the American Standards Association, Incorporated.

4. Identification

4.1 Each film shall be marked **SMPTE — ASA — PH22.57 — Buzz-Track.** This marking shall be printed lengthwise in the picture area, the spacing between consecutive titles to be approximately 12 in.

5. Film Length

5.1 The film shall be supplied in 100-ft lengths.

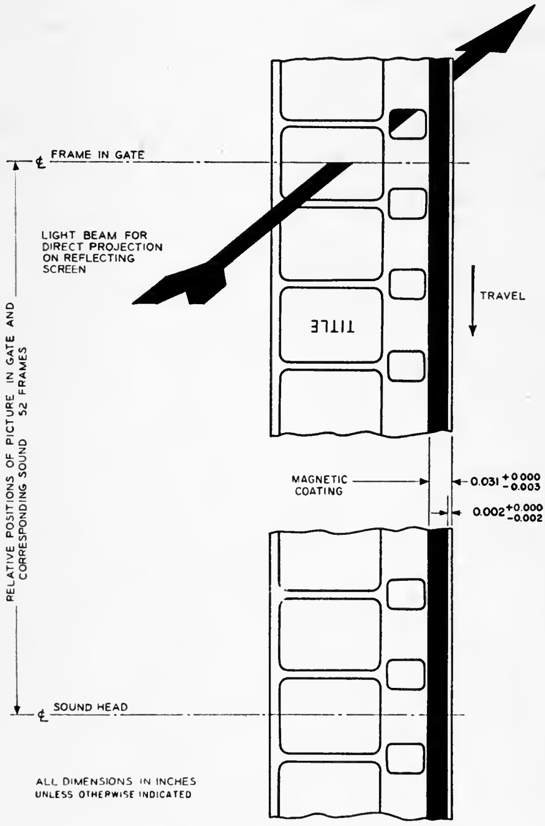
NOTE: A test film in accordance with this standard is available from the Society of Motion Picture and Television Engineers.

Proposed American Standard

Magnetic Sound Specifications for 8mm Motion-Picture Film

(Third Draft)

PH22.88



The magnetic coating in the above drawing is on the side of the film toward the lamp on a projector arranged for direct projection on a reflection-type screen.

Projection Speeds — 24 frames per sec for professional use.
18 frames per sec for amateur use.

NOT APPROVED

Proposed American Standard

35mm Magnetic Flutter Test Film

(Third Draft)

PH22.98

1. Scope

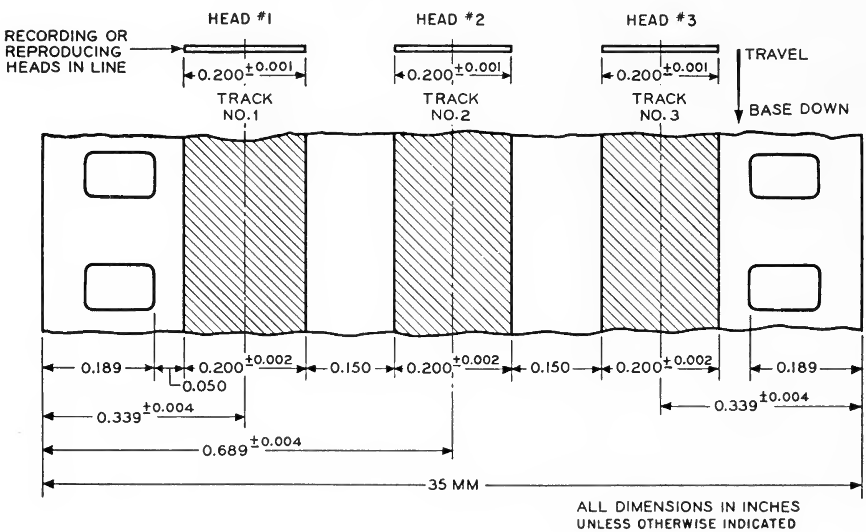
1.1 This standard specifies a 3000-cycle, fully coated, magnetic sound test film for use in determining the presence of flutter in 35mm magnetic sound reproducers.

2. Test Film

2.1 The test film shall have an original magnetic sound recording.

2.2 The coating position and direction of travel shall be as specified in American Standard PH22.86-1953, 200-Mil Magnetic Sound Tracks on 35mm and 17½mm Motion-Picture Film, or the latest revision thereof approved by the American Standards Association, Incorporated, and the base shall be coated from one row of perforations to the other row, or from edge to edge.

2.3 Three sound records shall be recorded in accordance with the dimensions specified in American Standard PH22.86-1953, or the latest revision thereof, and as shown in the drawing.



NOT APPROVED

2.4 The recorded frequency shall be 3000 ± 25 cycles per sec with a recording speed of 96 perforations per sec or 90 ft per min.
2.5 The modulation of the recording shall be such that the total harmonic distortion does not exceed 2½%.

2.6 The total rms flutter of the sound recorder shall not exceed 0.1% and the flutter amplitude shall not exceed 0.05% (as defined in Proposed American Standard Z57.1, Method of Determining Flutter Content of Sound Recorders and Reproducers).

3. Film Stock

3.1 The film stock used shall be of the low-shrinkage, safety type, cut and perforated in accordance with American Standard Z22.36-1947, Cutting and Perforating Dimensions for 35-Millimeter Motion Picture Positive Raw Stock, or the latest revision thereof approved by the American Standards Association, Incorporated.

4. Film Length

4.1 The film shall be supplied in 50-ft lengths or multiples thereof.

5. Identification

5.1 Each test film shall have suitable identification markings.

NOT APPROVED **PH22.98**

Proposed American Standard

35mm Magnetic Azimuth Alignment Test Film

(Third Draft)

PH22.99

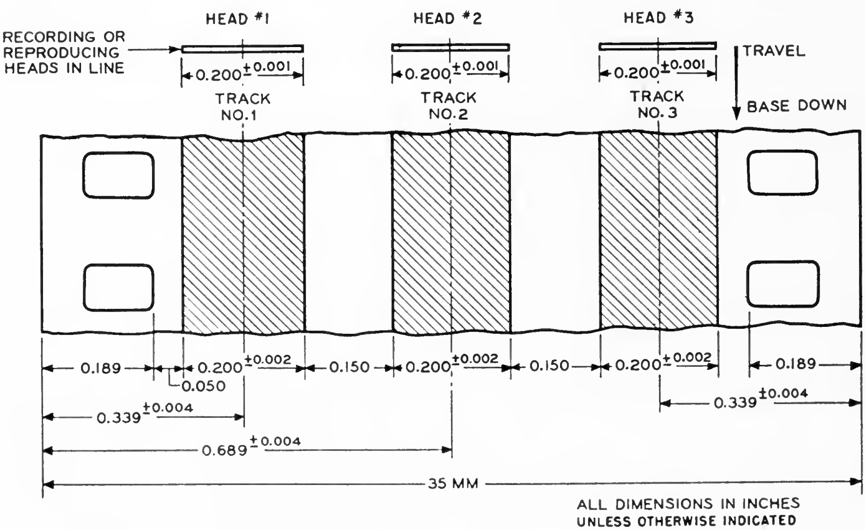
1. Scope

1.1 This standard specifies a test film to be used in aligning the azimuth of magnetic heads on 35mm magnetic recording and reproducing equipment where the head width is not greater than 0.200 in.

2. Test Film

2.1 The test film shall have an original recording of an 8000-cycle sinusoidal tone with a film speed of 96 perforations per sec or 90 ft per min.

2.2 Three sound records shall be recorded in accordance with the dimensions specified in American Standard PH22.86-1953, 200-Mil Magnetic Sound Tracks on 35mm and 17½mm Motion-Picture Film, or the latest revision thereof approved by the American Standards Association, Incorporated, and as shown in the drawing.



NOT APPROVED

2.3 The sound record shall have correct azimuth to within ± 3 min of arc.

2.4 The recorded level at 8000 cycles shall be that level which results from an input current to the magnetic head which is 1 db below the 400-cycle current input which would give a total harmonic distortion of 2½% when that 400-cycle tone is reproduced.

2.5 The coating position and direction of travel shall be as specified in American Standard PH22.86-1953, or the latest revision thereof, and the base shall be coated from one row of perforations to the other row, or from edge to edge.

3. Film Stock

3.1 The film stock used shall be of the low-shrinkage, safety type, cut and perforated in accordance with American Standard Z22.36-1947, Cutting and Perforating Dimensions for 35-Millimeter Motion Picture Positive Raw Stock, or the latest revision thereof approved by the American Standards Association, Incorporated.

4. Film Length

4.1 The film shall be supplied in 50-ft lengths or multiples thereof.

5. Identification

5.1 Each test film shall have suitable identification markings.

NOT APPROVED **PH22.99**

American Standards PH22.75–1953 and PH22.90–1953 16mm A and B Windings, and Aperture Calibration of Lenses

Two American Standards approved by the American Standards Association on December 17, 1953, are published on the following pages. These two standards were published previously for trial and comment in the October 1952 and February 1953 *Journals*, respectively.

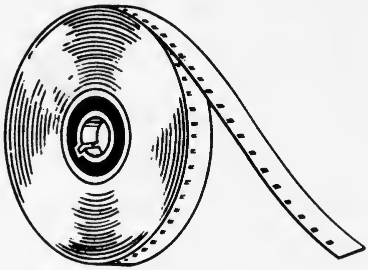
American Standard

A and B Windings of 16mm Film, Perforated One Edge

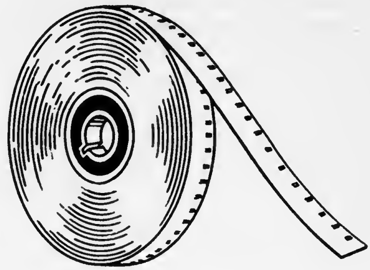
ASA
Reg. U.S. Pat. Off.

PH22.75-1953

*UDC 778.5



Winding A
Emulsion side in



Winding B
Emulsion side in

(With the types of winding described below, the emulsion side of the film shall face the center of the roll.)

1. Scope

1.1 The purpose of this standard is to insure a uniform method of designating the type of winding (the location of the perforated edge) when ordering or describing 16mm raw-stock film with the perforations along one edge.

2. Film on Cores for Darkroom Loading

2.1 When a roll of 16mm raw stock, perforated along one edge, is held so that the outside end of the film leaves the roll at the top and toward the right, winding A shall have the perforations along the edge of the film toward the observer, and winding B shall have the perforations along the edge away from the observer. No preference for either type of winding is implied, since both types are required for use on existing equipment.

3. Film on Spools for Daylight Loading

3.1 When the film is wound on a spool with a square hole in one flange and a round hole in the other flange, it shall be specified as winding B when wound as described for B above and with the square hole on the side away from the observer. Windings other than winding B, on spools, are considered as special-order products.

Appendix

(This Appendix is not a part of American Standard A and B Windings of 16mm Film, Perforated One Edge, PH22.75-1953.)

A1. The types of winding covered by this standard are limited to those which are in general use.

A2. It is recognized that film on spools, with a square hole in one flange and a round hole in the other, can be wound in other ways than that described as winding B, and that for special purposes these windings may be supplied commercially.

Approved December 17, 1953, by the American Standards Association, Incorporated
Sponsor: Society of Motion Picture and Television Engineers

*Universal Decimal Classification

Printed in U.S.A.
AS 1½M254

Price, 25 Cents

American Standard
Aperture Calibration of Motion-Picture Lenses

ASA
Reg. U.S. Pat. Off.

PH22.90-1953

*UDC 778.5

1. Scope

1.1 The purpose of this standard is to define the *f* and *T* numbers used to express the relative aperture of a photographic objective. A second purpose is to establish means for calibrating the diaphragms of objectives in both the *f* and *T* systems, with suitable tolerance specifications.

1.1.1 The *f* number of a lens represents a true geometrical measure of the relative aperture.

1.1.2 The *T* number is a photometrically determined measure of the relative aperture of a lens adjusted to take proper account of the lens transmittance, so that the illuminance in the center of the lens field will be the same for all lenses at the same *T*-stop setting. This assumes that the object is a uniform plane diffusing surface perpendicular to the lens axis.

1.2 It should perhaps be mentioned that the photometric calibration of a lens diaphragm as contemplated by the *T* system of diaphragm marking established by this specification is only one step in extending the control for the purpose of producing negatives of a desired uniform density. The density of a negative is dependent upon the illumination and reflectance of the object photographed, the correctness of the diaphragm marking, the absorption of the lens, the accuracy of timing of the exposure, the uniformity of the emulsion employed, and complete control of the processing. The application of the *T*-stop system is designed to improve the control as regards correctness of diaphragm marking and absorption of the lens. The importance and need for this particular control increases as the control of the other factors enumerated is improved.

2. Theory

2.1 The illuminance at the center of the image of a uniform plane extended object perpendicular to, and centered on, the lens axis, when the lens has a circular aperture, is given by:

$$E = \pi t B \sin^2\theta \qquad (1)$$

In this formula: E is the illuminance in lumens per unit of area; t is the lens transmittance, expressed as the ratio of emerging flux to entering flux for a beam sufficiently narrow to pass through the lens without obstruction by the lens mount; B is the object luminance in candles per square unit; and θ is the semi-angle of the cone subtended by the circular exit pupil of the lens at the point where the lens axis intersects the image plane.

2.2 If the lens can be assumed to be aplanatic, that is, to be free from spherical aberration and to satisfy the sine condition, and if the object is very distant, then the value of sin θ will be given by:

$$\sin\theta = \frac{Y}{f} \qquad (2)$$

where Y is the semidiameter of the circular *entrance* pupil of the lens and f is the focal length. The validity of this equation may be seen by reference to Fig. 1, remembering that, in a lens having the type of correction assumed in this paragraph, the principal planes of Gauss are in reality portions of spheres centered about the axial object and image points, respectively.

2.3 If the lens aperture is not circular, which will often occur when the iris is partly closed, the angle θ has no meaning. In such a case, we may define the *effective diameter, D′*, of the entrance pupil in terms of its area, A, by:

$$A = \frac{\pi D'^2}{4} \qquad (3)$$

Approved December 17, 1953, by the American Standards Association, Incorporated
Sponsor: Society of Motion Picture and Television Engineers

*Universal Decimal Classification

Printed in U.S.A.
ASA½M254

Price, 50 Cents

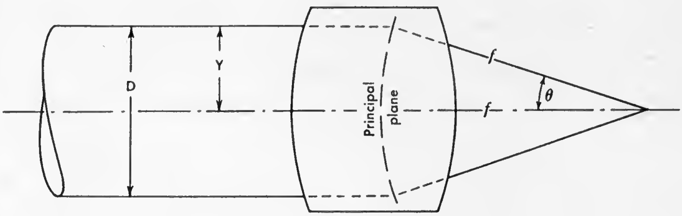


Fig. 1

whence $$D' = 2\sqrt{\frac{A}{\pi}} \quad (4)$$

2.4 For an aplanatic lens, we may now replace $\sin\theta$ by $D'/2f$, and the image illuminance equation (1) becomes:

$$E = \pi\, t\, B\, (D'/2f)^2$$

whence by equation (4), we find:

$$E = t\, BA/f^2 \quad (5)$$

3. Definition of *f* Number

3.1 For a lens of the type assumed, having a circular aperture, which is perfectly corrected for spherical aberration and satisfies the sine condition, and which is also assumed to form an image in air of a very distant object, the *f* number of the lens is defined by the equation:

$$f\text{ number} = \frac{f}{D} = \frac{1}{2\sin\theta_0} \quad (6)$$

where θ_0 is the semiangle of the cone subtended by the circular exit pupil of the lens at the point where the lens axis intersects the plane of the image of the assumed distant object, and the *entrance* pupil has a diameter, *D*.

3.2 If the entrance pupil is not circular, this relation becomes:

$$f\text{ number} = \frac{f}{D'} = \frac{f}{2}\sqrt{\frac{\pi}{A}} \quad (7)$$

following the reasoning of Section 2.3.

3.3 If the aperture is circular, but the lens does not satisfy the sine condition, then f/D will not be equal to $1/(2\sin\theta)$. In such a case, the *f* number of the lens is to be defined by $1/(2\sin\theta)$ rather than by the ratio f/D. This value is chosen because both the image illuminance and the depth of field of the lens depend directly on $\sin\theta$. In such a lens, then, the marked *f* number will not be equal to the simple ratio of the focal length to the diameter of the entrance pupil.

3.4 The procedure for measuring the *f* number of a lens with a distant object is given in Section 11.

3.5 In terms of *f* number, equation (1), giving the image illuminance, becomes:

$$E = \pi\, t\, B/4(f\text{ number})^2 \quad (8)$$

4. Effective and Equivalent *f* Number of a Lens Used at Finite Magnification

4.1 If a lens with a circular aperture is used to form an image at a finite magnification, *m*, the image illuminance will, as always, be given by equation (1).

4.2 The *Effective f number* of the lens, which is to be used to determine the image illuminance by equation (8), is then defined by:

$$\text{Effective } f\text{ number} = \frac{1}{2\sin\theta_m} \quad (9)$$

where θ_m changes as the magnification *m* increases.

4.3 For an infinitely thin lens, or for a thick lens in which the entrance and exit pupils coincide with the first and second principal planes, respectively, and in which the light beam is limited only by the iris diaphragm, the Effective f number will be related to the f number by:

$$\text{(Effective } f \text{ number for magnification } m) = (f \text{ number})(1 + m) \quad (10)$$

4.4 However, many lenses cannot be regarded as being "thin," and in such cases the Effective f number at a finite magnification will not* be equal to the infinity f number multiplied by $(1 + m)$. However, the photographer knows from long experience that he should always multiply the marked f number of a lens by $(1 + m)$ in order to determine the Effective f number at a finite magnification, m. Therefore, in order that this procedure can continue to be used, it is suggested that if a lens is designed to work at or near some particular finite magnification, m, the aperture markings should be engraved with the "Equivalent f number" defined by:

$$\text{Equivalent } f \text{ number} = \left[\frac{\text{Effective } f \text{ number at magnification } m}{1 + m}\right] \quad (11)$$

5. Definition of T Number

5.1 When lenses are marked in accordance with the f system, differences of value in the factor t of equation (1) are completely ignored, with the consequence that for a given f-setting of the diaphragms, even though correctly marked, the exposures made with different lenses may vary greatly, this variation arising from a variation in the number of component elements of the different lenses and from the large differences in the values of transmittance that exist between coated and uncoated lenses. The T system defined in this section is a new system of diaphragm graduation designed to compensate for this variation. With the T system of graduation, the image illuminance in the center of the field is independent of the variations in lens structure enumerated above.

* For example, an afocal lens of symmetrical construction can be used as a printer or copying lens at unit magnification. The Effective f number is then equal to the f number of the half system, but since the focal length of the whole lens is infinite, no meaning can be given to the f number of the whole system. For other examples see: R. Kingslake, "The effective aperture of a photographic objective," J. Opt. Soc. Am., vol. 35, pp. 518–520 (1945).

5.2 For a lens used with a distant object, the T number is defined as the f number of an ideal lens having 100 percent transmittance and a circular aperture, which would give the same central-image illuminance as the actual lens at the specified stop opening.

5.3 Hence, for a lens with a circular aperture, following the argument of equation (8):

$$T \text{ number} = \frac{f \text{ number}}{\sqrt{t}} \quad (12)$$

and for a lens with an entrance pupil of any shape and area, A, the corresponding formula is:

$$T \text{ number} = \frac{f}{2}\sqrt{\frac{\pi}{t\,A}} \quad (13)$$

5.4 In practice, however, it is expected that the normal procedure will be to re-engrave the diaphragm ring on the lens at a series of definite T numbers, rather than to measure the T number corresponding to each of the existing marked f numbers.

5.5 It may be remarked again that the T number is a photometrically determined quantity, whereas the f number is a geometrical quantity. Since the T numbers are determined photometrically, they automatically take account of the size and shape of the aperture, the actual focal length of the lens, the lens transmittance, and any internally reflected stray light which may happen to strike the film at the center of the field (such as in a flare spot). It is implicit in the T number system of aperture markings that every lens should be individually calibrated.

5.6 For a lens designed to be used at finite magnification, the engraved T number will correspond to the Equivalent f number defined by equation (11).

5.7 The procedure for measuring the T number of a lens is given in Section 13.

6. Standard Series of Aperture Markings

6.1 The diaphragm ring of a lens shall be marked at every whole stop on either system. A "whole stop" is taken to represent an interval of double or half the image illuminance, corresponding to a ratio of $\sqrt{2}$ or $\sqrt{0.5}$ in the diameter of a circular lens aperture. By convention, the series of whole stop numbers to be used are accurately:

0.71, 1.00, 1.41, 2.00, 2.83, 4.00, 5.66, 8.00, 11.3, 16.0, 22.6, 32.0, ...

6.2 These marks shall be engraved on the lens as follows: 0.7, 1, 1.4, 2, 2.8, 4, 5.6, 8, 11, 16, 22, 32. The maximum aperture of the lens shall be marked with its measured *f* number or *T* number, stated to one decimal place. These recommendations are in accordance with American Standard Lens Aperture Markings, Z38.4.7-1950.

6.3 In setting the lens aperture, it is assumed that the diaphragm ring will always be turned in the closing direction, and not in the opening direction; this is to eliminate backlash effects.

7. Subdivision of a Whole Stop

7.1 If it is desired to subdivide a "whole stop" interval, we may refer to a fraction, *S*, of a stop, defined so as to yield a ratio of image illuminance, *R*, equal to 2^S or $(0.5)^S$. Then, for any given illuminance-ratio, *R*, the corresponding fraction of a stop will be given by $S = (\log R)/(\log 2) = 3.32 \log R$. A few typical examples are given in the following table:

Fraction of a Stop (S)	Illuminance Ratio (R)
one-tenth	1.072 or 0.932
one-sixth	1.122 or 0.891
one-quarter	1.189 or 0.841
one-third	1.260 or 0.793
one-half	1.414 or 0.707
two-thirds	1.587 or 0.630
three-quarters	1.682 or 0.594
a whole stop	2.0 or 0.5

7.2 When engraving a lens, each whole stop interval may be divided into three subdivisions by dots or marks (not numbered), the dots being at "thirds of a stop," namely, 0.7, 0.8, 0.9, *1.0*, 1.13, 1.27, *1.4*, 1.6, 1.8, *2.0*, 2.2, 2.5, *2.8*, 3.2, 3.6, *4.0*, 4.5 5.0, *5.6*, 6.3, 7.1, 8.0, 9.0, 10.0, *11.3*, 12.7, 14.2, *16*, 18, 20, *23*, 25, 28, *32*, ...

7.3 Each stop interval is divided into three parts so that the lens apertures will agree with the exposure-meter markings stated in American War Standard for General-Purpose Photographic Exposure Meter, Z38.2.6-1946, 3.4.2, Relative Aperture Scale, page 6. The same cube-root-of-two series is used for the Exposure Index of a film. (See American Standard Method for Determining Photographic Speed and Exposure Index, Z38.2.1-1947, page 11.) One-third of a stop represents a logarithmic illumination ratio equal to 0.1, which is the transmittance of a neutral density of 0.1. The ratio of successive circular stop diameters is equal to $\sqrt[6]{2} = 1.123$.

8. Symbols

8.1 Lenses calibrated on the *f* system should bear the designation *f/* or *f:* followed by the numerals (see American Standard Lens Aperture Markings, Z38.4.7-1950).

8.2 Lenses calibrated on the *T*-stop system should bear the designation *T* or *T*- followed by the numerals.

9. Accuracy of Marking (f System)

9.1 The *maximum* opening of a lens on the *f* system shall be marked with an accuracy of ± 12 percent of area, or ± 6 percent of diameter.*

NOTE: Since in most factories a blanket calibration is generally used for the *f* apertures of a complete run of lenses of the same type, the smaller openings may be in error by ± 25 percent of area, or ± 12 percent of diameter (one-third of a stop), particularly in

* In accordance with American Standard Marking of Focal Length of Lenses, Z38.4.4-1942, the engraved focal length of *lenses for still picture photography*, must be within ± 4 percent of its true value, and in accordance with American Standard Lens Aperture Markings, Z38.4.7-1950, the measured diameter of the maximum entering beam shall be at least 95 percent of the quotient obtained by dividing the engraved focal length by the engraved *f* number. Thus by combining these tolerances we find that the diameter of the maximum lens aperture may be in error by as much as 9 percent. This represents an error in area of 18 percent, or one-quarter of a stop, which is felt to be unnecessarily large for the maximum aperture. The tolerances on aperture marking for motion-picture objective lenses allows less latitude than that provided for still picture camera lenses, because of the stricter requirements in cinematography on the same continuous length of film using different lenses.

short-focus lenses. These figures are based on the assumption that the iris will always be closed down to the desired aperture and not opened up from a smaller aperture, to eliminate backlash effects.

10. Accuracy of Marking (T System)

10.1 Since each lens is individually calibrated, an accuracy of one-sixth of a stop (10 percent in illumination or 5 percent in diameter) becomes entirely possible throughout the whole range of the diaphragm scale. This is assuming that the diaphragm is always closed down to the desired aperture and not opened up from a smaller aperture, to eliminate backlash effects.

10.2 Alternatively, the manufacturer should be prepared to guarantee this accuracy even though each stop marking may not be individually determined.

10.3 It may be of interest to indicate the approximate magnitude of this tolerance. Since 5 percent in diameter corresponds to 5 percent in *f* number, a lens of aperture nominally *f*/2 may be anywhere between *f*/1.90 and *f*/2.10. A lens nominally *f*/4.5 may lie between *f*/4.28 and *f*/4.72; and a nominal *f*/8 may lie anywhere between *f*/7.6 and *f*/8.4.

11. Measurement of *f* Apertures (Distant Object)

11.1 The procedure for measuring the *f* number of any lens having a circular diaphragm aperture is described in American Standard Methods of Designating and Measuring Apertures and Related Quantities Pertaining to Photographic Lenses, Z38.4.20-1948, paragraph 3.

11.2 If the entrance pupil is noncircular, it is necessary to measure its area. This may be done conveniently by mounting a point source of light, such as a small hole in front of a lamp bulb or a 2-watt zirconium lamp, at the rear focal point of the lens, and allowing the light beam which emerges from the front of the lens to fall upon a piece of photographic material. After processing, the recorded area is measured with a planimeter and applied in equation (7). If the lens is too small for this procedure to be employed, it may be placed in a suitable telecentric projector working at a known magnification (a workshop profile projector is suitable), the back of the test lens being towards the source of light. The entrance pupil then will be projected onto the screen of the projector at a known magnification, whence its area can be determined with a planimeter.

12. Measurement of *f* Apertures (Near Object)

12.1 To measure the Effective *f* number of a lens when used with a near object, it is necessary to determine the angle θ in equation (9). This may be done by using a point source of light at the correct axial object position, and measuring the diameter of the emerging beam at two widely separated planes a known distance apart. A simple computation will enable the semicone-angle θ to be determined.

12.2 The *Effective f* number is defined by $1/(2 \sin \theta)$; and the *Equivalent f* number for engraving on the lens barrel will then be equal to the Effective *f* number divided by $(1 + m)$, where m is the image magnification. (See section 4.4 above.)

13. Photometric Calibration of a Lens

13.1 General Requirements

13.1.1 Since *T*-stops are based on a measurement of the illumination produced by the lens at the center of the field, it is first necessary to define the latter term. For the purpose of illumination or flux measurements, the term "center of the field" shall be taken to mean any area within a central circle approximately 3 mm in diameter for 35mm or 16mm frames, or 1.5 mm in diameter for 8mm frames.

13.1.2 The light used in making the determination shall be white,* and the sensitivity characteristic of the photoelectric receiver

* Specifically, a tungsten filament lamp operating between 2900 and 3200 K.

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shall approximate that of ordinary panchromatic emulsion.† It is considered that these factors are not at all critical and no closer specification than this is necessary. Obviously, errors will arise if the lens has a strongly selective transmission, but such lenses would be undesirable for other reasons.

13.1.3 The incident light shall fill a circular field whose angular diameter is no more than 10 degrees in excess of the diagonal of the intended angular field of the lens itself. During measurement, the light shall traverse the lens in the direction ordinarily employed in photography.

13.1.4 The lens should be carefully examined before calibration to ensure that there are no shiny regions in the barrel which would lead to flare or unwanted stray light, since this would vitiate the measurements badly. The lens surfaces should be clean.

13.2 Corner-to-Center Ratio. Having calibrated the stop markings of the lens on the *T* system by one of the methods to be described, the observer may, if desired, determine in addition the ratio of corner illumination to center illumination, at full aperture and preferably at other apertures also. For this purpose the 3-mm (or 1½-mm) hole shall be used first at the center of the field, and then moved outwards until its rim is touching the top and side limits of the camera gate. This distance is shown in Table 1.

Table 1

Gate, Mm	Radial Shift of Hole, Mm
35 (16.03 × 22.05)	11.5
16 (7.47 × 10.41)	4.5
8 (3.51 × 4.80)	2.0

13.3 Extended-Source Method of *T*-Stop Calibration (distant object)

13.3.1 This method of lens calibration has been described by Gardner[13] and Sachtleben,[9] the underlying theory being given by McRae.[4] It is based on filling the lens with light from an extended uniform source, and placing a metal plate *in the focal plane* of the lens with a 3-mm hole (or 1.5-mm for 8mm film) at its center. The light flux passing through the hole is measured by a photocell arrangement. This flux is then compared with the flux from the same source passing through the same hole from an open circular aperture of such a size and at such a distance from the plate that it subtends the desired angle θ referred to in equation (2) above. The greatest care is necessary to ensure that the extended source is really uniform, and also constant throughout the measurements. The open circular aperture is used as the "ideal lens with 100 percent transmittance" referred to in Section 5.2.

† A suitable cell is one having an S-3 surface, combined with a Corning 9780 glass filter about 2.5 mm thick.

13.3.2 It should be noted that this procedure measures the *T*-stop Aperture Ratio of the lens directly, regardless of whether or not the lens is aplanatic.

13.3.3 In practice, the photocell reading for each whole *T*-stop number is first determined for a series of open apertures, at a fixed distance from the plate. The lens is then substituted for the open aperture with the 3-mm hole accurately in its focal plane, and the iris of the lens is closed down until the photocell meter reading produced by the lens is equal to each of the successive open-hole readings. The full *T*-stop positions are then marked on the diaphragm ring of the lens. The intermediate third-of-a-stop positions may be found with sufficient accuracy by inserting a neutral density filter of 0.1 or 0.2 behind each open aperture in turn and noting the corresponding photocell readings.

13.3.4 Table 2 which lists aperture diameters may be useful. They are based on a distance of 50 mm from aperture to plate. (It is important to remember the difference between sine and tangent, and that the aperture diameter is *not* found merely by dividing 50 mm by the *T* number.)

13.3.5 A single set of apertures is sufficient to calibrate lenses of all focal lengths, since the only factor involved is sin θ, and that is fixed by the aperture used. The apertures should be bevelled to a sharp edge, and well blackened on both sides.

13.3.6 The extended source should be uniformly bright over its useful area to within ± 3 percent. (This can be tested with a suitable

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Table 2

Desired T Number	Value of θ = Cosec^{-1} (2 × T number), Degrees	Diameter of Aperture = 100 tan θ, mm
0.5	90	∞
0.71	45	100
1.00	30	57.74
1.41	20.708	37.80
2.00	14.478	25.82
2.83	10.183	17.96
4.00	7.181	12.60
5.66	5.072	8.88
8.00	3.583	6.26
11.31	2.533	4.42
16.00	1.791	3.12
22.63	1.266	2.21
32.00	0.895	1.56

telephotometer, or a small hole in an opaque screen can be moved around in front of the source, and any consequent variations in photocell reading noted.) The source conveniently may be a sheet of ground glass covering a hole in a white-lined box containing several lamps mounted around the hole and shielded so that no direct light from the lamps falls on the ground glass itself.

13.3.7 The photocell receiver conveniently may be of the phototube type with a simple direct-current amplifier.* Care must be taken to ensure that the phototube sensitivity and the line voltage do not change between making readings on the open aperture and on the lens itself; to guard against this, some convenient turret arrangement is desirable, with the lens on one side and the open aperture on the other so that the two may be interchanged and compared immediately with each other by merely turning the turret.

13.3.8 To measure the corner-to-center illumination ratio, the lens is set in position and the 3-mm hole and the photocell are displaced laterally by the desired amount. The photocell reading is noted at axial and corner positions, and the corresponding light ratio found from a calibration curve of the photocell meter.

* Suitable systems are the "Electronic Photometer" model 500 (Photovolt Corporation, 95 Madison Ave., New York, N. Y.), and the "Magnephot" (W. M. Welch Scientific Co., 1515 Sedgwick St., Chicago, Ill.). It is felt that a barrier-layer cell, although desirable for reasons of simplicity, has insufficient sensitivity for accurate determinations of the smaller apertures unless a galvanometer of exceptionally high sensitivity is employed.

13.4 Collimated Source Method of Lens Calibration

13.4.1 This method has been described by Daily [11] and Townsley,[14] the underlying theory being embodied in Section 5 above. Light from a small source (a 5-mm hole covered with opal glass and strongly illuminated from behind) is collimated by a simple lens, or an achromat if preferred, of about 15 inches focal length and 2 inches aperture. This gives a collimated beam which will be focused by the test lens to form a small disk of light in its focal plane. This circle of light will be less than the prescribed limit of 3-mm diameter for all lenses under 9 inches in focal length. Uniformity of the collimated beam can be checked by moving a small hole in an opaque screen across the beam, and any variations in the photocell reading noted.

13.4.2 For the comparison unit, an open aperture is used of diameter equal to the *focal length* of the lens divided by the desired *T* number. This aperture is first mounted in front of an integrating sphere with the usual photocell detector, and the light from the collimator is allowed to enter the aperture. The aperture plate is now replaced by the lens, the iris diaphragm is closed down to give the same photocell reading, and the *T*-stop number is engraved on the iris ring. The intermediate thirds of stops can be added by using 0.1 or 0.2 density filters, as described in Section 13.3.3.

13.4.3 To guard against drift and line-voltage variations which might occur between the readings on the comparison aperture and on the lens, it is convenient to leave the known standard aperture in place in front of the sphere, and to insert the lens into the beam in such a position that the little image of the source falls wholly within the standard aperture. The meter reading should then remain the same no matter whether the lens is in or out of the beam. A second plate with a 3-mm aperture should be placed over the comparison aperture while the lens is in place to stop any stray light which may be reflected from the interior of the lens.

13.4.4 It should be noted particularly that if this method is used, the focal length of the lens must be measured separately, and a suitable set of open apertures constructed for use with it. However, by suitable devices, one single set of fixed apertures may be used for all lenses, as described by Townsley.[14]

13.4.5 It should also be noted that this procedure measures *f* number as the ratio of *f/D,* and the measurement is thus influenced by the state of correction of the lens in regard to spherical aberration and sine condition.

13.4.6 The corner-to-center ratio at any desired aperture can be conveniently determined by simply rotating the lens through the desired field angle ϕ and comparing the photocell reading with its value for the lens axis. The light-flux ratio can then be read off a calibration curve for the photocell system, and converted to the desired corner-to-center illumination ratio by multiplying it by $\cos^3\phi$. (Note that this procedure will be correct only in the absence of distortion, but no motion-picture lens is likely to have enough distortion to cause any significant error.)

13.5 *T*-Stop Calibration at Finite Magnification

13.5.1 To use the *extended* source method (see Section 13.3), it is only necessary to mount the metal plate at the desired image distance from the lens instead of placing it in the focal plane. The open apertures used for comparison must be calculated to have an opening corresponding to the desired *Equivalent f* number multiplied by $(1 + m)$. This is because the illuminance given by the lens is really being compared with the *Effective f* number of the open hole, but the engraving must be done at each standard step of the *Equivalent f* number (see Section 12.2).

13.5.2 The *collimated* source method cannot be used to calibrate a lens at finite magnification.

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Lens Calibration

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75th Convention

Members will soon be receiving the "First and Final" announcement of the Spring Convention. As was predicted, features of the Advance Program have been combined with the customary folded postcard and members thus have advance program information and hotel rates in one package. Applications for reservations, which should be sure to mention the SMPTE, or the reservation cards enclosed with the announcements, should be mailed without delay to the Front Office Manager, Hotel Statler, Washington, D.C. Rates are:

Single	\$ 8.00 to \$11.00
Double	11.00 to 15.00
Twin	14.50 to 19.50
Suites (for one or two) .	29.50 to 37.00

The program has fully materialized along the substantial and broad outlines given in the three previous *Journals* — twelve sessions with fifty technical papers, from Monday noon to Friday night, May 3–7, at the Hotel Statler in Washington, D.C.

2d Int'l Symposium on High-Speed Photography

In October 1953 the first international conference in this field was held in Washington under the sponsorship of the SMPTE, with John H. Waddell as Symposium Chairman. The second symposium, which is being arranged by the Association Française des Ingénieurs et Techniciens du Cinéma, with the cooperation of a number of other European film associations, will take place in Paris September 22–28, 1954.

The organizing committee consists of Lucien Bull (Chairman), director of the Marey Institute, P. Libessart, H. Schardin, P. Fayolle, J. Vivié, P. Naslin and delegates from participating countries. Applications or enquiries concerning the symposium should be addressed to the Secretary of the Organizing Committee, P. Naslin, Laboratoire Central de l'Armement, Fort de Montrouge, Arceuil (Seine), France.

There will be papers on the optical, mechanical, electrical and electronic techniques and instruments in use in high-speed photography, and also on the applications of these techniques to the study of rapid events in the various scientific and technical fields. The three official languages of the symposium will be French, English and German.

Fees will be 1000 francs for authors of papers and 2000 francs for others attending. Within the limits of the available space there will be an opportunity to exhibit equipment, subject to the payment of a 20,000 franc fee per exhibit (\$1.00 equals 350 francs).

1954 Membership Directory — New Members

There is still time: Copy for the new Directory will be assembled at the end of this month. Three-fourths of the membership have returned the envelope and clipping sent two months ago with the membership dues invoices. Prompt replies are now in order, to be sure that listings are safely and properly in the new Directory.

New Members as a *Journal* column feature is being discontinued, for economy's sake, at least until the new Directory is issued.

SMPTE Officers and Committees: The roster of Society Officers and the Committee Chairmen and Members were published in the April 1953 *Journal.* A new roster is being prepared for the April 1954 *Journal.*

Section and Subsection Meetings

A meeting of the **Southwest Subsection** was held on November 20, 1953, at the Continental National Bank auditorium, Fort Worth, Texas. Guest speakers were George H. Brown, Director, Systems Research Laboratory, Princeton, N.J., and Robert E. Shelby, Director, Color TV Systems and Development, NBC New York, who discussed "Compatible Color Television and Its Relationship to the Broadcaster." Their discussion covered the NTSC compatible color television signal in terms of brightness signal combined with a color subcarrier which conveys hue and saturation information, and reviewed a number of the factors which influenced the choice of the color subcarrier frequency as well as some which influenced compatibility. Some transmitter requirements and related measuring equipment and methods were also described. Attendance was over 80, including some IRE members as guests. *W. W. Gilreath*, Secretary-Treasurer, Southwest Subsection, 3732 Stanford St., Dallas, Texas.

The **Pacific Coast Section** met on Tuesday evening, November 17, 1953, at Republic Studios in the San Fernando Valley. The program included a description and tour of the new Republic sound stage units, a screening of selections from a recent Republic wide-screen production, and a discussion of stereophonic sound by one of the top experts in the field.

Members were particularly impressed by the new television film production sound stages and the excellent technical discussion by Dan Bloomberg concerning their design and use. The color quality of a reel of daily rushes from the current production, *Johnny Guitar*, starring Joan Crawford and processed by Consolidated Film Industries, was also most impressive.

Following the opening film, William B. Snow discussed "Stereophonic and Pseudo-Stereophonic Sound in Motion-Picture Production," including an explanation of the use of such clues as intensity, quality and arrival time in creating the stereophonic illusion. Factors which aid in pickup were shown to cause complications in the listening room. Particular emphasis was given to the relationship between true stereophonic pickup and the pseudo-stereophonic methods employing electrical controls during re-recording to produce sound movement.

Approximately 450 persons attended the meeting. The Pacific Coast Section is very grateful to Mr. Bloomberg and his staff for their excellent cooperation in making the many arrangements necessary for handling a meeting of this size.—*Philip G. Caldwell*, Secretary-Treasurer, Pacific Coast Section, ABC Television Center, Hollywood 27, Calif.

The January 5th meeting of the **Pacific Coast Section,** held at the NBC Television Studios, Burbank, was an unusually interesting and popular program—an operating demonstration of color television, including the new NBC Mobile Color TV Unit brought to Southern California for the color telecast of the New Year's Day Rose Parade.

The meeting was conducted informally with a demonstration running continuously from 2:00 to 4:30 p.m., and during this time the audience was free to visit the exterior pickup location where two color cameras were in use, the mobile pickup unit and a stage where four color receivers were in operation. Attendance was about 600, and response to the picture quality and color was enthusiastic.

This very successful program was made available to the Section through the courtesy of O. B. Hanson, Vice-President and Chief Engineer of NBC New York, and A. H. Saxton, Manager, Technical Network Operations, NBC Hollywood.—*E. W. Templin*, Secretary-Treasurer, Pacific Coast Section, c/o Westrex Corp., 6601 Romaine St., Hollywood 38, Calif.

The **Central Section** held a meeting at the Western Society of Engineers building on January 21. The large auditorium was used and some 80 members were in attendance. "Basic Chemistry of Photography," a paper presented by Thomas T. Hill, Chief Photographic Chemist, Ringwood Chemical Corp., outlined the role of chemistry and of chemicals in the photographic process from the standpoint of motion-picture engineering. After describing the physical properties and constitution of motion-picture film, Mr. Hill discussed some of the controls which are possible with chemicals and the precautions necessary to avoid difficulty with developer and fixing solutions.

A second paper, "A History of Color Film Reproduction," was given by Ray Balousek, President of Grossman-Knowling, Detroit. The first part of this paper was concerned with the historical highlights of color cinematography from the first two-color Kodachrome and two-color Technicolor imbibition process up to the present 35mm negative-positive color films. The second part discussed present-day problems in regard to color slide film animation, particularly with negative-positive films. Illustrative slides were shown on all phases of these processes and a slide film reviewed some of the historical color procedures.—*K. M. Mason*, Secretary-Treasurer, Central Section, 137 North Wabash Ave., Chicago.

Obituaries

George K. Spoor, one of the pioneers of the motion-picture industry, died November 24, 1953. He was 81 years old.

He was born in Highland Park, Ill., left school at 16 and went to work for the North Western Railroad. At the age of 23 he met the inventor of the magniscope, a precursor of the moving picture machine. George Spoor invested in it and in 1897 he and Gilbert M. (Broncho Billy) Anderson founded the Essanay Film Company in Chicago. Two years later he bought the rights to the kinedrome, a moving picture projector, and during the succeeding years, until the lot closed in 1916, the Essanay Company was the proving ground for many of the greatest stars of the silent films.

Also prominent as an inventor of motion picture equipment, Spoor worked for years on the three-dimensional process known as Natural Vision. A description of his achievements, after 7 years of experimenting, was published in the *New York Times* of August 21, 1923. In 1925 he showed 3-D films to an invited gathering in Chicago and comments such as "Clear as real life!" "This puts ordinary movies in a class with lantern slides!" and "Just like looking through a plate glass window!" flew thick and fast. However a 3-D film entitled *Danger Nights*, which was offered for public consumption in 1930, proved an economic failure.

Hyman Goldin died on January 6, 1954, in Toronto, He was 48 years old.

Mr. Goldin received his early education in Montreal and graduated from the University of Toronto. Until 1946 he was with Dominion Sound Equipments (Canadian Westrex), from 1946 to 1951 he was Chief Engineer of Gaumont-Kalee, Toronto, and since 1951 Chief Engineer of Perkins Electric Co., Toronto. During the war he was loaned to the Canadian Government and assisted in perfecting the intercommunications system used in Lancaster bombers. For the past three years he had been working as a consulting engineer on acoustic problems. He served on various committees of the SMPTE and in Canada was an active member of the Canadian Standards Association Committee Z7.1 on Motion Picture Photography.

Book Reviews

Television Broadcasting

By Howard A. Chinn. Published (1953) by McGraw-Hill, 330 W. 42 St., New York 36, N.Y. i-ix + 690 pp. + 10 pp. index. 346 illus. 6 × 9 in. Price $10.00.

This book is intended for the television broadcast operator. It should be particularly timely for the many radio engineers who face television operations for the first time, in the hundreds of new stations being built. It is a single complete reference volume covering the practical problems of television broadcast station construction and operation.

Mr. Chinn writes with authority befitting his stature and vast experience in the broadcast field. Those who share an acquaintance with Mr. Chinn can appreciate the patience and diligence which have gone into the book's preparation.

The book is readable. It is not so theoretical as to be discouraging, and yet the meat is there. For example, the synchronizing generator, which is the most difficult piece of equipment for the uninitiated to comprehend, is adequately explained. Sufficient information is given for a basic understanding of the gross differences among equipment types, so that the new engineer can choose. The presentation is exactly at the proper level for the intended audience.

The content runs the complete range from television fundamentals to color television. Considerable space is devoted to the image orthicon tube and the camera in which it is used. Field pickups and the appropriate equipment are discussed in some detail. Studio equipment, lighting, projectors and film problems are well treated, as are the TV transmitter, antennas and feed lines. Even building planning is presented, with many helpful hints for the new broadcaster. The chapter on color television covers the field-sequential system which was the law of the land at the time of the manuscript, but which has since been replaced by the compatible system of NTSC. However, there are many applications of the field-sequential system which well justify the treatment.

All through the chapters runs the theme of achieving a professional level of operations. It is clearly demonstrated that care with small matters will automatically resolve system difficulties and result in an operation of which the newcomer to television can be proud.

This volume deserves wide distribution in the radio and television field as a thoroughly practical operating handbook. It proves that television, while an electronic miracle, is still a creature of ordinary man; and that ordinary man can understand and control it. This book is wholeheartedly recommended to the membership of the Society for interesting reading and conscientious study. In preparing it, Mr. Chinn has rendered a valuable service to the television broadcast industry.—*A. E. Hungerford, Jr.*, General Precision Laboratory Inc., Pleasantville, N.Y.

Thermionic Vacuum Tubes and Their Applications, 6th ed.

By W. H. Aldous and Edward Appleton. Published (1952) by John Wiley & Sons, Inc., 440 Fourth Ave., New York 16, N.Y. 151 pp. + 98 illus. 4 × 6½ in. $2.00.

This little book treats conventional vacuum tubes, including magnetrons, klystrons and traveling wave tubes as to internal electron action and the applications thereof as amplifiers, rectifiers, frequency changers, oscillators, reactance tubes and relaxation devices.

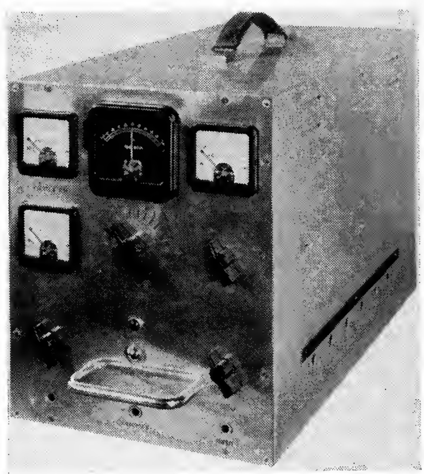
Numerous equations are given in explanation of the phenomena to the physicist and for purposes of design for the engineer. A terse approach has been taken and more factual information has been provided than would be surmised from the size of the volume.

The book is British: W. H. Aldous being on the Research Staff of the M. O. Valve Co. at the G.E.C. Research Laboratories, Wembley, England; and Sir Edward Appleton being Principal and Vice-Chancellor of Edinburgh University.

Over a hundred references are listed for further reading.—*Harry R. Lubcke*, Reg. Patent Agent, 2443 Creston Way, Hollywood 28, Calif.

New Products

Further information about these items can be obtained direct from the addresses given. As in the case of technical papers, the Society is not responsible for manufacturers' statements, and publication of these items does not constitute endorsement of the products.



The Gaumont-Kalee Flutter Meter is designed to measure small frequency variations of a given carrier frequency. If the meter is provided with a signal of the correct frequency and of suitable amplitude, variations from constant speed of the recording and/or reproducing machine can be measured. The instrument operates at a nominal carrier frequency of 3000 cycles/sec, but will tolerate up to 5% variation in mean carrier frequency, thus enabling measurements to be made on machines that are running off speed, or using film of disks whose recorded 3000-cycle tone is inaccurate.

The meter consists of a narrow-band amplifier, a limiter, a discriminator and detector, and a metering system, the whole unit being self-contained with its own power supplies. The input amplifier is tuned to 3000 cycles/sec and has a bandwidth of 1000 cycles/sec. It is provided with an input control for adjusting signal level. An amplitude limiter, which eliminates effects caused by signal level variations, is followed by a power amplifier which drives a discriminator operating at a mean frequency of 3 kc. The discriminator may be tuned from 2850 to 3150 cycles/sec to accommodate variations in mean carrier frequency. The error in the input frequency expressed as a percentage of speed is indicated on a scale. The input signal level at the discriminator, which is set up on a meter by means of a control in the limiter circuit, is maintained constant by the limiter.

The Gaumont-Kalee Flutter Meter is distributed in the U.S. by S.O.S. Cinema Supply Corp., 602 West 52d St., New York 19.

Employment Service

These notices are published for the service of the membership and the field. They are inserted for three months, at no charge to the member. The Society's address cannot be used for replies.

Positions Wanted

Motion-Picture Television Technician: 10 yr intensive skill and know-how related to 16-35mm cinematography, animation, recording (optical, tape, disk), editing, laboratory processing practice (black-and-white, color); also kinescope recording techniques; self-reliant; inventive; relocate if required; write: CMC, Technical Associates, 60 East 42d St., New York 17, N.Y.

Motion-Picture Cameraman: Retiring from Naval Service. 15 yr experience in camera operation, printing, processing, adm. and supervision of production crews. Desires position in TV, educational or industrial field, inaugurating a motion-picture program. Available after May 1954. Prefer West Coast. Write: W. W. Collier, 422 W. Jackson Ave., Warrington, Fla.

Positions Available

Wanted: Sound Engineer for New York film production studio, operation and maintenance on optical and magnetic sound equipment; electronics background essential. Send résumé to R. Sherman, 858 West End Ave., New York, N.Y.

Technical Photographer, age 27 to 38, for senior position with large California industrial research organization. Should be conversant with contemporary techniques for recording data; acquainted with microscopy, graphic arts and color processes. Job involves application of photographic techniques as experimental tool in research projects. Administrative experience helpful. Excellent career opportunity for an ingenious and inventive person. Retirement pension and other benefit plans. Application held in strict confidence. Write giving personal data, education and experience to Henry Helbig and Associates, Placement Consultants, Examiner Bldg., 3d and Market Sts., San Francisco 3, Calif.

Sound Engineer: Complete responsibility for sound control, including printing, processing, maintenance of standards, etc. Tri Art Color Corp., 245 West 55th St., New York 19, N.Y.

Motion-Picture Supervisor, GS-8: Duties as Chief of Motion Picture Section to include all phases of aeromedical research cinematography. Experience in planning, directing, lighting, color control, recording in single or double-system sound. Laboratory work requires experience with sensitometric control equipment, contact printers, automatic processors, Moviola, sound synchronization equipment, titlers, etc. For detailed information write: Photography Officer, USAF School of Aviation Medicine, Randolph Field, Texas.

Motion-Picture Sound Transmission Installer and Repairer, for the Signal Corps Pictorial Center, Long Island City, N. Y.—one at $2.59/-hr; one at $2.29/hr (40-hr week). Applicants for $2.29/hr position must have had 4½ yr progressively responsible experience in the construction, installation and maintenance of electronic equipment, of which at least 1½ yr must have been in the specialized field of motion-picture film, disk or magnetic sound recording or reproducing equipment. Applicants for $2.59/hr position must have had at least 5 yr responsible experience in the design, development and installation of electronic equipment, of which at least 2 yr must have been in the specialized field of motion-picture film, disk or magnetic sound recording or reproducing equipment. Must be familiar with filter design and transmission testing, involving the use of a wide variety of testing and measuring devices. Each year of study successfully completed in a residence school above high school level in electrical, electronic or radio engineering, may be substituted for the general, but not the specialized experience indicated above, at the rate of one scholastic year for each 9 mo. of experience. All applicants must be familiar with Western Electric and RCA systems. Obtain Form SF 57 at any first class Post Office or Government Agency; forward or bring completed form to Civilian Personnel Division, Signal Corps Pictorial Center, 35–11 35th Ave., Long Island City, N.Y.

Photographic Engineer: Wanted for design and development work involving application of film and associated equipment to monochrome and color TV systems. Prerequisites are BS or equivalent, and experience in at least one of the following motion-picture fields: (a) TV film applications, (b) processing laboratory design and operation, (c) camera and projector design or (d) sensitometry and densitometry. Please send résumé to Personnel Dept., CBS Television, 485 Madison Ave., New York 22, N.Y.

Sales Management Engineer: To head division manufacturing single optical track stereo sound system. Already adopted by major studio. Position requires knowledge of theater sound systems here and abroad. Reply to: Fairchild, Rm. 4628, 30 Rockefeller Plaza, New York 20, N.Y.

Engineer: To direct engineering of flying-spot TV projector with millisecond pulldown mechanism. Mechanism already developed and working. Reply to: Fairchild, Rm. 4628, 30 Rockefeller Plaza, New York 20, N.Y.

Wanted — Consultant technician: Thorough knowledge of Houston continuous double-head printer, Houston developing machines, Bell & Howell printers and Debrie Matipo step printer. Must put machines in running order and train operating personnel. Usual per day rate and plane fare to Puerto Rico. Address replies to R. J. Faust, Chief, Cinema Section, Dept. of Education, Commonwealth of Puerto Rico, Division of Community Education, P. O. Box 432, San Juan, Puerto Rico.

Wanted — Engineer for N.Y. Film Processing Lab: Opportunity for experienced individual to direct maintenance and engineering of color/-B&W printing and processing equipment. Submit complete résumé (replies strictly confidential) to: Irwin Young, Du-Art Film Laboratories, Inc., 245 W. 55 St., New York 19, N.Y.

Permanent Position: Open for versatile 16mm cameraman familiar with all phases of industrial production. Write McLarty Picture Productions, 45 Stanley St., Buffalo 6, N.Y.

Meetings

National Electrical Manufacturers Assn., Mar. 8–11, Edgewater Beach Hotel, Chicago, Ill.

Radio Engineering Show and I.R.E. National Convention, Mar. 22–25, Hotel Waldorf Astoria, New York

Optical Society of America, Mar. 25–27, New York

The International Sound Track Recording Convention has been announced by the Association of Radioelectricians, 10 Ave. Pierre Larousse, Malakoff (Seine), France, to be held in Paris, April 5–10, 1954, on sound-track recording processes and their extension to other fields of application. Radio and television networks and the motion-picture industry will participate with technical papers, an exhibition of equipment, and tours of plants and technical centers. Problems of standardization will be discussed.

The Calvin Eighth Annual Workshop, Apr. 12–14, The Calvin Co., Kansas City, Mo.

International Symposium on Information Networks (information from Microwave Research Institute, Polytechnic Institute of Brooklyn, 55 Johnson St., Brooklyn 1, N.Y.), April 12–14, Engineering Societies' Building, New York

Society of Motion Picture and Television Engineers, Central Section, Spring Meeting, Apr. 15, The Calvin Co. Sound Stage, Kansas City, Mo.

75th Semiannual Convention of the SMPTE, May 3–7, Hotel Statler, Washington

American Institute of Electrical Engineers, Summer General Meeting, June 21–25, Los Angeles, Calif.

Acoustical Society of America, June 22–26, Hotel Statler, New York

Illuminating Engineering Society, National Technical Conference, Sept. 12–16, Chalfonte-Haddon Hall, Atlantic City, N.J.

Photographic Society of America, Annual Meeting, Oct. 5–9, Drake Hotel, Chicago, Ill.

American Institute of Electrical Engineers, Fall General Meeting, Oct. 11–15, Chicago, Ill.

76th Semiannual Convention of the SMPTE, Oct. 18–22, Ambassador Hotel, Los Angeles

77th Semiannual Convention of the SMPTE, Apr. 17–22, 1955 (next year), Drake Hotel, Chicago

The International Commission on Illumination is to hold its next international conference in Zürich, Switzerland, June 13–22, 1955 (*next year*). Offers of papers should be addressed to the Chairman of the Papers Committee (A. A. Brainerd), 1015 Chestnut St., Philadelphia 7. Manuscripts must be in the hands of the Central Bureau between Oct. 1 and Dec. 31, 1954.

78th Semiannual Convention of the SMPTE, Oct. 3–7, 1955 (next year), Lake Placid Club, Essex County, N.Y.

Television Lighting Routines

By WILLIAM R. AHERN

The lighting installation of NBC Studio 8H features convenient facilities for setting up the many and varied lighting routines required by today's television shows. Efficient operation of these facilities reduces studio usage for lighting purposes, and consequently increases the number of shows which can be staged each week. This paper describes the installation, and provides a documentary account of the process of lighting a typical dramatic show.

In the short space of less than a decade, television lighting has gone through a complete revolution. The older camera tubes required extremely high light levels of 800 ft-c or more. Terrific heat from the lights poured onto actors and scenery, and was accepted as a normal part of the television operation. Little attention could be given to the nuances or delicacies of lighting when the main problem was one of getting enough light. The photographer who came to the studio for some publicity shots often preferred to set up his own lights to produce the type of picture his public had come to expect. Today, the same photographer is running into trouble at the other end of the scale. Quality is excellent, but light levels are getting too low. On finding a low key or dark scene, the photographer is now likely to ask, "Is there going to be more light in here? I've got to get a picture."

It would seem, offhand, that the lower light level means chiefly that shows can be lighted quicker and with less trouble; but progress in lighting has steadily improved the pictures in their quality. We are now portrait painting with light. We are pinpointing areas and there are close-ups to take care of, just as in motion-picture work. Actually more careful lighting and, consequently, more lighting time are required to give the type of picture at home that the public has come to expect, and that the client has a right to expect.

The client has two good reasons for wanting to keep lighting time down. One is the direct cost to him for the lighting director's time, the electricians, and so forth. The other is less obvious. If a show ties up a studio for two days (one day to light the show, and another for rehearsal and air time), the studio is out of use for other shows. This, of course, means that the TV station or network must have more studios, and hence make greater charges to clients.

Presented on October 7, 1953 at the Society's Convention at New York, by William R. Ahern, National Broadcasting Co., 30 Rockefeller Plaza, New York 20. (This paper was first received Dec. 9, 1953, and in revised form Jan. 14, 1954.)

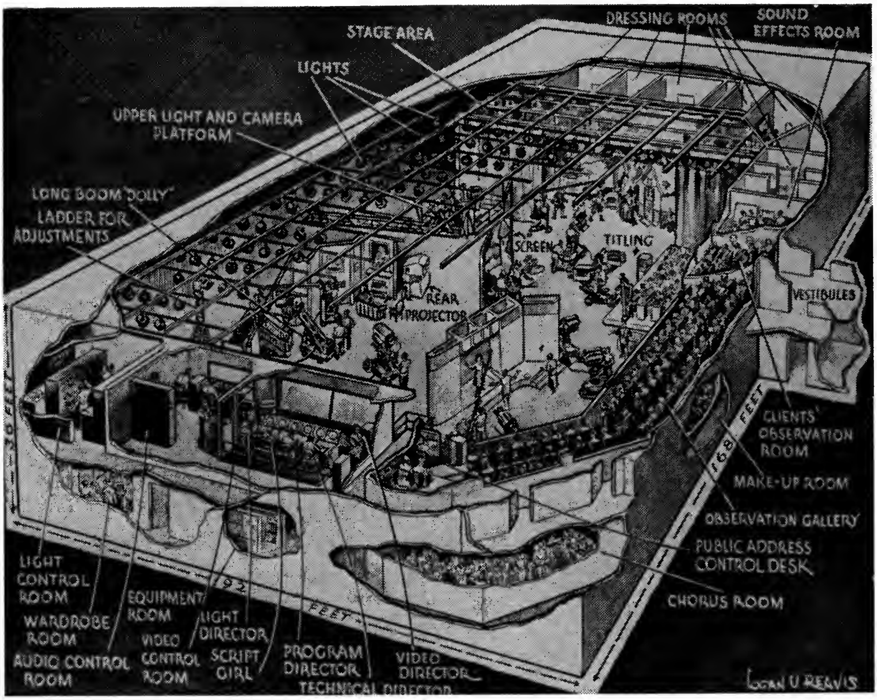


Fig. 1. Sectional view of NBC Studio 8H.

There are two ways of keeping lighting time down. The first is to provide complete and convenient facilities in the studio to minimize the amount of time it takes to light a show. However, caution is necessary. It is easy to develop an elaborate system that seems operationally efficient, but proves to be complicated, unreliable, and wasteful of maintenance time and labor. It is necessary to strike a balance. The second way is to apply the techniques or tricks of the trade, that lighting directors have developed over a period of years. Both ways will be demonstrated. The facilities at NBC's Studio 8H in New York, which is one of the newer studios, will be described. Then, the lighting of a typical show will be reviewed. This will be presented chronologically, step by step, to show how the lighting was performed.

Lighting Facilities

Figure 1 is a cutaway view of Studio 8H, which shows the position of the lighting switchboard. With the lighting switchboard elevated in this position, the electrician can look out over the scenery in the whole studio and see where his lights are, and which ones are on. The control room, also elevated, is to the right in the middle of the picture. The video engineer and the lighting director sit together at the righthand side of the control room. Note that the studio is approximately 92 ft by 168 ft.

Some of the lighting equipment in the studio is shown in Fig. 2. There are lighting pipes hanging on steel cables which run over sheaves in the ceiling to counterweights on the side, just like a stage. In television there is a real marriage of motion-picture tech-

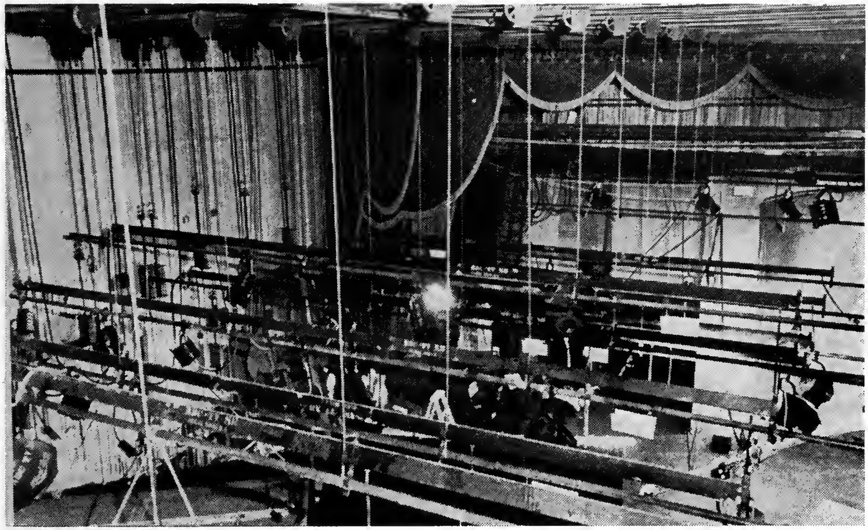


Fig. 2. Looking down through lighting pipes.

niques with stage techniques. The material above the hanging clamps on the lamps resembles stage techniques, with the counterweights, the steel cables, the lighting pipes that go up and down, and so forth; while below are Fresnel-type spotlights, barndoors, scrims, and so forth, as in motion pictures. The lighting pipes in this studio are spaced about 4 ft apart, run all the way across the studio, and can be raised to a height of approximately 35 ft.

One of the first things done in lighting a show is to set the height of the lighting pipes. In this studio there have been Westerns with live horses and very high scenery, for which the pipes were pulled up about 30 ft in the air, against the ceiling, to give the necessary clearance. In most dramatic shows, the sets are about 10 ft high, and the pipes are brought down to about 12 ft from the floor. Manila ropes operate the counterweights from the floor to change the height of the pipes.

On each lighting pipe is a raceway from which the lighting outlets hang. The raceway is fed from a multiconductor cable that loops down from the ceiling. The outlets, or pigtails, or lighting receptacles, are on 2-ft leads, and are spaced about 5 ft apart. A lamp can be hung and plugged in at any outlet with no waste of time to find a cable or jumper. In this studio there are approximately 425 of these outlets, to practically eliminate the time consuming procurement and use of extension cables. About 24 of these outlets are spread around the floor of the studio. Also, all outlets are numbered to identify circuits back at the switchboard.

Figure 3 shows the distribution section of the switchboard which provides for choice of interconnections between outlets in the studio and dimmers or switches in the control section of the board. On the right is a patch-cord type of interconnection where each plug protruding above the horizontal surface is connected to a retractable cable that eventually feeds an outlet in the studio. On the vertical surface are the receptacles which are permanently wired to the various dimmers

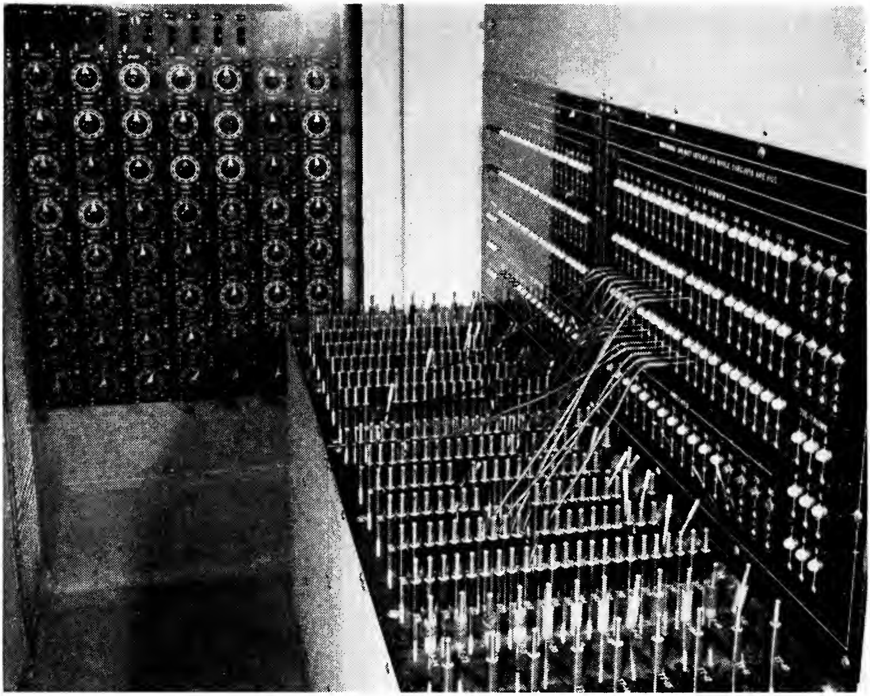


Fig. 3. Interconnection or distribution section of lighting switchboard.

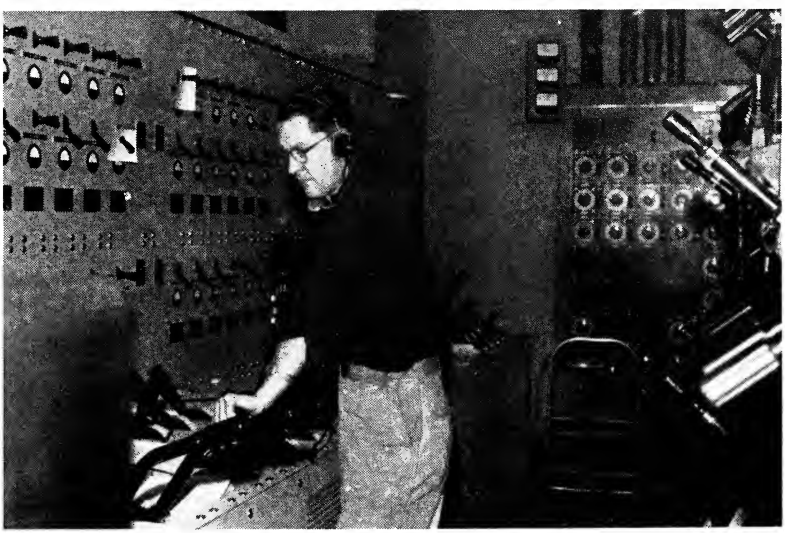


Fig. 4. Control section of lighting switchboard.

and switches in the control section of the switchboard. This permits complete flexibility in energizing an outlet or group of outlets from any dimmer. In the background is another type of interconnection. Each one of those knobs in its square panel represents an outlet in the studio. By turning the knob pointer to the number of the desired dimmer and pushing the knob in, that outlet is then connected to the proper dimmer. This is a rotary selector type of operation for getting the circuits in the studio through to whatever dimmer is desired.

The operating position of the board is shown in Fig. 4. On the right is a vertical-type board with the various dimmer handles protruding. The electrician is at a console-type board. On both boards, dimmer handles are mechanically arranged so that they can be worked in groups or individually. Also each dimmer has a load meter to preclude circuit breakers from killing lights through overloads. The object in the foreground is a picture monitor for the electrician's use. If, for instance, an actor coming into a room snaps the light switch on the wall, the electrician can time his cue perfectly by watching the picture on the monitor. A headset keeps the electrician in direct two-way contact with the lighting director in the control room.

In this studio there are about 1500 amps available. Approximately 120 dimmers are used to give the flexibility needed to light a show in a minimum of time.

Lighting Practice

Having described the equipment, we may proceed to the lighting of the September 10th *Martin Kane* show, which is on from 10 to 10:30 E.S.T. on Thursday nights.

Approximately two weeks before the show, the cast has been chosen and the script selected. The lighting director gets his script about a week before the show. About six days before the show, the cast gets together daytimes for rehearsals in a hotel ballroom, or some similar place out of the studio. They rehearse their lines and then, as time goes on, start to walk through their parts until the day before the show. In this dry rehearsal they're not only reciting the lines but are also performing the actions they will follow in the studio. There are no cameras. Tapes on the floor delineate where the scenery will be; and chairs are placed to denote furniture, doors and windows.

About 11:00 a.m. on the day before the show, the technical director of the show and the lighting director attend the dry rehearsal. When the lighting director comes to this rehearsal he receives two pieces of paper which help in lighting. One is the floor plan of the studio with the scenery shown in place. This is actually a scale print of the plan from which the scenery is set up. As he watches the dry rehearsal, the lighting director marks his floor plan, indicating actor's positions and actions. He also gets camera angles and microphone boom positions, which he marks on the plan. With this information he can start lighting the following morning.

The other piece of paper which the lighting director gets is called the *rundown*. The rundown shown in Fig. 5 happens to be for another show but is quite adequate to serve as an example. Notice that by telling the lighting director that Act One, Scene 1, is in the ranch house, pages 1–17 in the script, early morning, it gives him his mood and cues his lighting. Scene 3 is "twilight as scene begins, grows darker, dark by the time Starbuck enters." Here is an indication of the important use of dimmers to gradually change the scene during the show.

Although the lighting director has received the script a week or so ahead of time, and has read it, he knows that

		SCENE & LIGHTING SEQUENCE	
		ACT ONE	
SCENE 1	RANCH HOUSE	(1-17)	EARLY MORNING
SCENE 2	SHERIFF'S OFFICE	(17-24)	AFTERNOON
SCENE 3	RANCH HOUSE	(24-39)	TWILIGHT
		(AS SCENE BEGINS__GROWS DARKER__DARK BY THE TIME STARBUCK ENTERS)	

Fig. 5. "Rundown" or scene sequence and lighting sheet.

in the control room he will not be able to use it. He can't follow a script while critically observing pictures on the control room monitors. Instead, he marks up his cues on the rundown sheet and goes by that. Then, he memorizes his cues for light changes, and depends on the notes in his rundown for any additional help he may need during the show.

The clutter of confusion in Fig. 6 is what the studio looks like at 9:00 a.m. on the day of the show. This is when the lighting director pauses to reflect on his way of life. His thoughts run something like this, "By air time tonight it's got to look good, because you're going on, and there are no retakes in this business." The scenery has been put up during the preceding night by a night setup crew. However, the dressing of the sets, such as adding the pictures, the drapes, and all the detail, is to be done during the day.

The lighting director has four electricians to work with for this show. One of the electricians goes up on the board to patch in the circuits and set up the switchboard. The fly man meanwhile operates the manila ropes and the counterweights to adjust the height of the pipes for that day's show. Another electrician starts hanging lights. The scoops or floodlights which supply the base or fill light, are in a ring around the front of each set. These go up first in all sets so that the actors and the cameras can see to rehearse.

The lighting director knows from his dry rehearsal of the day before what sets are going to be rehearsed in next, so he lights an idle set. When the actors get ready to move into that set he moves out to another set and comes back and finishes later, if necessary. This means a lot of movement; but the lighting is being done on the same day as the show, and not taking up a second day or night in the studio.

By 11:00 o'clock rehearsing with cameras starts. The actors are in and the show is fully rehearsing. From 12:30 until 2:15 is devoted to what is called *blocking the show.* The cameramen are told where to put their cameras for the shots, everybody takes time to lay out each shot, actors are positioned right, and then, later in the day, all the shots are put together and run through with continuity. From 2:15 to 3:15 the camera crew and the actors eat; and during this time the lighting director (he has eaten earlier with his crew) takes over and has the whole studio to himself and continues his lighting. From 3:15 to 5:30 blocking the show is continued.

During blocking and while he is lighting, the lighting director glances at the picture monitors on the studio

Fig. 6. Studio as lighting starts.

Fig. 7. One of sets in September 10 *Martin Kane* show, seen from above.

floor to get a rough idea of the completed lighting and camera shots.

From 5:30 to 6:30 there is a "break" in which the actors get notes. Lighting can meanwhile continue. From 6:30 to 7:30 p.m. there is a *run-through*. This is rehearsing the show against time, trying to get it all done with no stops. (There will, of course, be some stops; an hour is allowed for rehearsing a half-hour show). During this run-through the lighting director is up in the control room with the video operator and the technical director. The lighting director wears his headset with which he can direct the man on the dimmer board to adjust the dimmers for the right mood or the right light level. Also, other headsets can be plugged in on the studio floor so that he can talk to the electricians there. During run-through the lighting director sits in the control room and makes notes. He has no occasion to stop the cast or the actors to change lights.

There is another break from 7:30 to 8:30, during which the cast gets notes, and the lighting director goes down on the floor and makes any changes that he considers necessary. Dress rehearsal is from 8:30 to 9:00. This is almost as it is going to be on the air. The lighting director moves up to the control room during *dress*. Between 9 and 10 o'clock, just before air time, the lighting director is again on the floor, making any last-minute changes. Then 10 to 10:30 is air time.

One scene in the show, *Adelaide's Apartment*, is shown in Fig. 7. The view is down through the lighting pipes, and shows the lighting units and the pigtails into which they are plugged. This scene used approximately 25 lighting units, namely: eight scoops or floods, out front; ten 500-watt spots, six 1000-watt spots; and one 2000-watt spot. Figure 8 is a different view of the same scene showing the lights overhead. Notice the patterns of light and dark, plus depth creating shadows, on the walls. At the top of the picture are the scoops for the base lights. On two 1000-watt spots, barndoors have been used to create the dark uppers and light bottoms on the two doors. The bars on the window are projected through by means of a 2000-watt spot which puts the bars on the curtain, showing there is some light outside. The walls of the set are lighted with one set of lights and put on one dimmer. The actors are backlighted to make them stand out from the walls and the backlights are on another dimmer. The base, or the flat front-fill, light is on a third dimmer. The key lights to give the character and shadows to actors are on a fourth dimmer.

The lighting director, in the control room, can by talking to the switchboard electrician, immediately change the mood of the scene. He can bring up the flat base lights from the front, and flatten out the scene—or, he can reduce the base and vary the dimmers to give the type of picture that the program and technical directors want.

This show has nine major scenes and six minor scenes to light; yet lighting can be done in one day of studio time.

Discussion

Murray Dick (School of Radio Technique, Inc.): Have you completely done away with fluorescent lighting?

Mr. Ahern: Actually we have very little of it in use at the present time, for several reasons. The units are quite uncontrollable in beam spread, and also, a dimmer is only now being developed and it is rather complicated. Fluorescent lighting by itself seems to give a pretty harsh complexion—you have to have incandescent to get the proper tonal renditions that the director likes. By the time that is done you find yourself using quite a bit of incandescent. Also, with incandescent you have greater flexibility, for fluorescent lighting units are bulky and heavy to move around.

Mr. Dick: Isn't there a great deal of infrared light coming from your in-

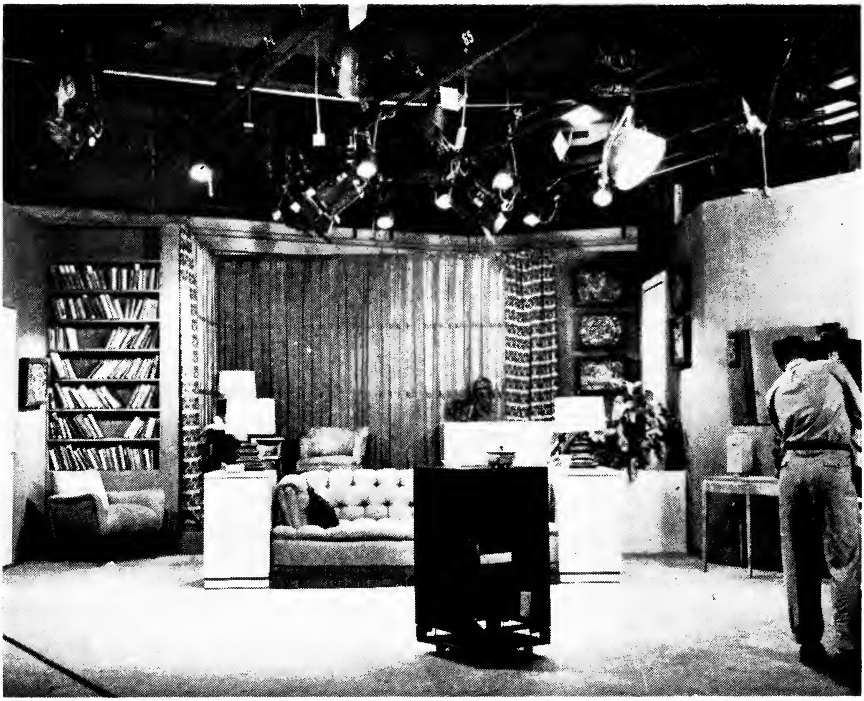


Fig. 8. One of sets in September 10 *Martin Kane* show, showing lighting arrangement.

Fig. 9. Technical director, video operator and lighting director in control room.

candescents which requires to be balanced, maybe with the use of a Wratten filter?

Mr. Ahern: The combination of incandescent light and the color response of the image orthicon, you will find, gives scene color brightness response very closely matching the eye. For instance, the new image orthicons now are low in the red, counteracting the lights which are high in the red.

Henry Roger (*Rolab Studios*): Would it be possible to eliminate some of the human element during the actual performance by running a perforated strip of paper, such as actuates a player piano, a device which would automatically operate the lights?

Mr. Ahern: We have in use a couple of devices that approach that. The Center Theater has a very excellent switchboard of the preset type, with approximately 10 preset setups. Just by flipping one lever, you can bring up any one of 10 combinations. Also the Colonial Theater has the preset board on which, during the rehearsals, you set up your combinations. When the show goes on you press one button and lights come up in the intensities which were set.

John P. Muller (*WDSU Broadcasting Services, New Orleans*): Do you set any light levels with meters or mechanical means, or does your director just watch it on the monitor?

Mr. Ahern: All our lighting directors have light meters. Of course, with experience you get to the point where you can light pretty much by eye. You then use the meter as a check before going up in the control room and talking to the video operator. He may ask whether the light is too low and the lighting director can give him the measurement in foot candles. The video operator then knows whether he's got a camera tube that's giving trouble.

Mr. Muller: What type of meter is used?

Mr. Ahern: It's a special Weston, model 915.

Stereography and the Physiology of Vision

By EDWARD LEVONIAN

The transmission of an image from the original scene to the 3-D screen involves several transformations, the last of which occurs in the spectator himself. Analysis of any transmission system or theory has significance only as it pertains to the capabilities of the human visual apparatus. The spectator must be considered an integral part — the most important part — of the transmission system, and, as such, the evaluation of any system should be preceded by, and based on, a knowledge of the limitations imposed by the physiology of vision. It is the purpose of this paper to investigate some of these limitations.

It is possible to analyze mathematically the transformation of an object in the scene to an image on the screen. Yet to analyze in this manner the ocular, neural and psychological factors involved in perception not only is beyond the present state of knowledge but also presents problems in relating effects to a coordination of numbers. Therefore, consideration will be given only to a few physiological effects that are related to stereography, and no causal relationships in regard to these effects will be investigated.

In any transmission system using mechanically independent units, we must expect differences between the two aspects in registration, illumination, color, and in any other factor which is separately controlled for each aspect. To what extent such differences may exist without adversely affecting the intent of transmission is a problem which can be determined precisely only by experimentation, which, because of the large number of variables involved, is beyond the scope of this paper. However, since the body of knowledge in the field of physiological optics is more advanced than in the less explored field of film technology, it has been found economical to investigate certain evidences offered by the field of the physiology of vision which seem to have a bearing on the 3-D film. Such an investigation cannot replace experimentation in the theater, and, at best, can only lead to approximations which indicate the order and direction of mechano-optical accuracies which must

A contribution submitted September 24, 1953, by Edward Levonian, 1533 Fourth Ave., Los Angeles 19, Calif. This paper is an abridged portion of a thesis for an MA degree at the University of Southern California. Members of the thesis committee were William C. Blume, Chairman; Nicholas Rose; Paul A. White.

be respected in order for successful stereography to result.

The necessary relationship between the 3-D film and human vision is immediately apparent: the errors in transmission cannot be greater than the limitations imposed by the spectator's visual ability.

Steadiness of the Composite Image

The two aspects on the screen will usually vibrate with respect to each other. Such vibration is caused by a lack of film registration in cameras, printers and projectors, and by mechanical vibrations in apparatus. Under such conditions the fundamental frequency of the unsteadiness in each aspect is 24 cycles/sec.

In order to determine whether such unsteadiness can be adequately handled by the average spectator's visual abilities, it is necessary first to define such unsteadiness in terms related to physiological optics, and secondly, to determine the magnitude of the unsteadiness. This unsteadiness is adequately expressed in visual terms by the variation in the angle formed by straight lines passing through the right and left eyes and their respective point pairs on the screen. In the horizontal plane this angle is referred to as the convergence angle, while in the vertical plane it is known as the angle of vertical divergence.

As regards the magnitude of the intermittent variation in these angles, it has been determined that even in the extreme case of 16mm filming without registration pins, enlargement to 35mm, and projection on a standard 24-ft screen, the maximum intermittent variation in the convergence angle for a spectator seated 75 ft from the screen is about 6′ of arc, while the intermittent variation in vertical divergence is no more than 3.5′ of arc.[1]

Is this order of variation visually acceptable? Since the values cited will probably be the maximum encountered in the 3-D film, these values will be referred to the limitations of the visual apparatus, for, if it can be shown that these extreme values can be handled, it will be known that less demanding cases will certainly be acceptable.

First a determination should be made of whether such a variation creates the perception of a vibrating composite image. With the discriminating device (Polaroid glasses, for instance) removed, both aspects are seen by both eyes. Now the two aspects are seen to vibrate with respect to each other, for the visual Snellen acuity of the average spectator for normal motion-picture brightness is about one minute of arc, while the visual vernier acuity, which is more significant, is even less. With the application of the discriminating device can the spectator still detect movement in the composite image?

With the discriminating device inducing fusion, individual perception of either aspect is absent. Thus, the detection of unsteadiness can only be the detection of unsteadiness of the composite image. Conceivably this unsteadiness might be detected if, by fixation, each eye were to follow its respective vibratory aspect movement. However, the reaction time of the extraocular muscles is about one-tenth of a second,[2] so the eyes cannot possibly follow the 24-cycles/sec image movement due to a lack of film registration. Whether the reflex period is influenced by certain cerebral rhythms[3] or by the time delay at the synapses (junction points between the brain and the receptors in the retina) is not of particular importance for this discussion except that if it is the latter, there exists the indication that movements of points other than those fixated could be detected even less because of the added number of synapses for receptors outside the fovea.

Nevertheless, stereopsis exists even in the absence of willful innervation of the extrinsic muscles,[2] so it cannot be assumed that unsteadiness cannot be detected simply because the eyes cannot follow the excitation frequency. Even when the spectator fixates a point, each eye undertakes independent excursions; the magnitude of such movements has a bearing on the steadiness of the composite image. Such movements are of two types: larger movements occurring at about 10 per sec,[2] and smaller twittering movements occurring at 50–100 per sec.[4] Only the former need concern us.

Since the larger excursions occur at the speed of 200–500′ of arc per sec,[5] the magnitude of each movement will be as great as 20–50′ of arc. These values have been substantiated by the independent method of Clark.[6] He found that when a spectator views a stereogram, each random binocular movement averages about 45′ of arc, each eye moving independently. The magnitude of this movement is independent of the fixation distance and of whether the fixation point is isolated or in context.

The precise amount the eyes vary during fixation need not be determined for our purposes. Suffice it to say that when the spectator is viewing a disparate picture presentation, each eye moves in a random and independent fashion. Since such eye movements are not sensed, it should be expected that relative movement between stimulus and receptor of an even higher frequency would not be sensed either. In the 3-D film such a relative movement occurs between one aspect and its respective eye, and hence, if detection of unsteadiness in the composite image is to occur, it must be due to some cause other than the frequency of the movement.

One such cause might be an excessive amplitude in the intermittent movement of either aspect. It appears that an image is fused and appears steady as long as it falls on a prescribed area of the retina about the fovea. It is often assumed incorrectly that in order for fusion to occur, an object which is imaged at one point in the retina of one eye must also be imaged at an anatomically corresponding point in the second eye. It is known, however, that as long as the object is projected on even noncorresponding points in the second eye, stereopsis will result as long as the noncorresponding points are confined to a restricted area. Such an area is called Panum's area. Thus, as long as the projection of the movement of a point on the screen falls within Panum's area, fusion should occur, and, for such a case, the composite image will appear steady because the mind cannot discriminate between retinal movement and aspect movement, for both types of movements are at a frequency higher than the willful eye movement frequency.

A knowledge of the angular extent of Panum's area is necessary in order to determine whether the intermittent variation of the convergence angle falls within this area. Charnwood gives the angular horizontal extent of Panum's area for the average spectator as 25′ of arc.[2] A similar value is given by Davson, who points out, however, that the ability to fuse point pairs falling on noncorresponding retinal points is influenced by the desire to see a single steady object, and this in turn is a function of the psychological condition of the spectator.[7] Thus it is seen that Panum's area may vary greatly not only among spectators but also in a single spectator at different times.

Other factors besides desire to fuse influence the size of Panum's area. Ellerbrook, using Polaroid filters to discriminate point pairs, separated such points in an experiment designed to determine at what point fusion disappears. He has found that the ability to fuse increases with an increase in the following factors: the period during which displacement takes place, peripheral fusional stimuli as against point sources at the fovea only, image size, brightness, the degree to which one image is the same size as the other, and image definition.[8] The implication of these results to motion pictures is clear. The film composer has little control over the first two, but he can influence the spectator's ability to fuse point pairs by attention to the remaining factors.

Panum's area appears to have the form of an ellipse with the major axis being horizontal.[7] This would indicate a need for greater accuracy of film registration in the vertical direction than in the horizontal. The minor axis is only somewhat greater than the vertical intermittent movement of 3.5′ mentioned previously for the extreme case of 16mm filming with 35mm projection. However, the horizontal intermittent movement of 6′ of arc computed for the same problem is well within the major axis of Panum's area. Thus, for this transmission problem considered and for all general 3-D transmission, it is seen that the human visual apparatus is able to handle the errors in transmission due to a lack of film registration. However, simply because fusion will result and the composite image will appear steady, there is no guarantee that the spectator will not exhibit some other undesired effect, such as fatigue. Experimentation in the theater will best determine such possibilities.

Location of the Composite Image

The geometry of transmission allows the calculated image to be located theoretically anywhere in the theater space. However, there are limitations to the apparent location of the composite image, limitations which are psychological and physiological. Only the latter will be considered in this paper.

One physiological limitation on the location of the composite image is due to the fact that, in stereography, accommodation and convergence are separated, the former being relatively fixed for the screen distance and the latter varying as a function of the geometry of image presentation and viewing interest. The unnatural separation of accommodation and convergence could have two principal effects: (1) it could influence depth sense, and (2) it could restrict the location of the image. Does the separation of accommodation and convergence impose significant limitations on the placement of the composite image?

The influence of this separation on depth sense, or location sense of the composite image, has not been established for the 3-D film, so reliance is placed on more general information to indicate a probable answer, and even then no definitive theory exists.

For instance, the psychologist Gibson[9] feels that neither accommodation nor convergence can influence location sense because neither is a stimulus for depth perception. He states that both accommodation and convergence are results of more primary stimuli: accommodation, the reflex to the stimulus of blur at the fovea; convergence, the reflex to the stimulus of disparity; and that the image matrix on the retina, inasmuch as it is a function of distance by way of its gradient in size, texture, disparity and other depth cues, is a sufficient stimulus to depth perception. Gibson concludes that "present evidence makes it doubtful that they [accommodation and convergence] furnish any data for depth perception."[9]

This may well be true, but whether it is the gradients of blur and disparity on the retina or accommodation and convergence themselves which are the stimuli is a point of academic interest which need not be considered in the present discussion. In this paper the terms accommodation and convergence will continue to be used instead of blur and disparity without implying that the former terms are actually the factors which influence depth perception.

To dissociate accommodation and convergence in order to determine their separate effect on depth perception presents problems in experimentation because of the reciprocal influence of one on the other.[6] To the extent that dissociation is possible, however, Swenson has found that the spectator senses the image at a point somewhere between the accommodation and convergence distances.[10] Generally the image appears about three-fourths of the way between the accommodation and convergence distances and closer to the latter. This result should not be directly applied to the peculiar conditions of stereography, but Swenson's results seem to indicate that, in the absence of other cues, convergence (or retinal disparity gradient) is a stronger cue to depth perception than is accommodation (or retinal blur gradient). However, the fact that the accommodation distance has some effect on depth perception might indicate that a transmission geometry which uses only the projection theory of vision to determine the calculated location of the composite image will result in a picture which is compressed toward the screen.

The comparative effects of accommodation and convergence on depth perception are of less importance than a comparison of the relative influence of either accommodation or convergence on depth perception as against that of other cues, cues such as binocular parallax, size of retinal image, interposition, aerial perspective, linear perspective, detail perspective, motion parallax, brightness, and light and shadow. The first one is a binocular cue, the remainder monocular. When binocular cues are in conflict with monocular, it is generally the latter which influence the determination of depth, particularly for distant images. For instance, the cue of interposition, or overlapping, is stronger than stereopsis.[12] The reason for the superiority of monocular cues may lie in the fact that binocular vision requires some outside factor to give it scale,[13] and this outside factor is usually one or more monocular cues.[2] All the monocular cues, with the exception of motion parallax, are present in 2-D and 3-D motion pictures. Therefore, it is concluded that accommodation at the screen or convergence at the image has relatively little influence on the depth perception of the composite image.

In regard to the second possible effect of the separation of accommodation and convergence, namely the effect of restricting the location of the image, it is known that this separation or dissociation is not unlimited. Furthermore, it is not necessarily constant for any one spectator, being a function partly of the psychological condition of the spectator.[11] For the average case in the clinic, the ability to diverge the eyes is about three prism diopters (about 1.5°), while adduction, the ability to converge the eyes, is about nine diopters (about 5°) for each eye. Since in normal stereography the spectator's eyes are accommodated essentially for optical infinity, the spectator is theoretically able to diverge from infinity to minus 7 ft and to converge on a point only $1\frac{1}{2}$ ft in front of his eyes. The dissociation of accommodation and convergence seems theoretically not to restrict the location of the image in the theater.

However, comfortable viewing is impossible unless the extreme planes are kept within certain limits, and Duke-Elder states that as a good general rule people are able to exercise only the middle third of their relative convergence without visual fatigue.[11] The approximate application of this rule to motion pictures means that visual comfort is maintained as long as the geometrical location of the image is restricted to the region from 5 ft in front of the spectator to infinity. The restricting case for all spectators is, of course, determined by the distance from the screen to the closest spectator.

Duke-Elder's rule would indicate a maximum separation of point pairs equal to the human interocular. However, it is emphasized that the rule just given for the limitation of the image in the theater is only approximate, and research is needed to determine the extent, in both magnitude and period, to which infraction of this rule is possible for the unique conditions of the 3-D film. Experimentation should be undertaken in the theater, not the clinic, so that usual motion-picture conditions apply. It may well be that for such conditions some divergence can be tolerated with comfort, particularly if the nearest plane is not as close to the spectator as has been shown possible. Such a possibility has its advantages in the mechanics of filming.[17]

Vertical Disparity of Point Pairs

So far only intermittent movements of point pairs have been considered. However, mechanical, optical and human errors in transmission will also result in steady errors in the placement of point pairs. Such steady errors will usually last for at least the duration of the shot. The effect of steady errors in the distance between point pairs in the horizontal direction is to create an error in the intended location of the composite image. The extent of this error in location is a function, partly, of the psychological condition of the spectator,[1] and hence will not be considered in this paper. The effect of steady errors in the distance between point pairs in the vertical direction is to create a condition forcing one eye to be angled upward. This unnatural act may cause either fatigue or diplopia, depending on its magnitude.

The extent to which one point of a point pair can be elevated without causing diplopia will now be investigated. Ellerbrook separated point pairs in the vertical direction in order to find out at what separation diplopia first occurs.[8] He found that fusion still maintains as long as the amplitude of vertical divergence is not much greater than 1°, a value corroborated by Davson.[7]

Again, for the same extreme case of 16mm filming with 35mm projection in a regular theater, it has been computed that the addition of all normal mechanical, optical and human errors cannot cause a vertical divergence greater than 14′ of arc for a spectator seated 75 ft from the screen.[1] This maximum value is for point pairs located at the top or bottom of the screen; vertical disparity between point pairs at the center of the screen will be considerably less. Even for the closest spectator to the screen, the vertical divergence induced by a vertical disparity in point pairs is much below that necessary to cause diplopia.

It has already been mentioned that Ellerbrook found that the ability to fuse vertically disparate point pairs increases as the fusional stimuli approach the periphery of the visual field.[8] It is fortunate that a greater amplitude of vertical divergence is possible for peripheral stimuli, because vertical disparity of point pairs increases at the corners of the screen due to the convergences of cameras and projectors (keystoning).

Disparity in Magnification

It can be shown that the convention of always keeping longer lenses on the same side, say the left, in both filming and projecting would help minimize the effect of the disparity in the magnification of the two aspects due to a disparity in lens focal lengths.[1] Nevertheless, such a disparity in magnification may exist, and, as can be shown, may cause an error in the apparent location of the composite image, particularly at the side borders where horizontal disparity is most evident.[1] Magnification disparity may also cause headache, fatigue or diplopia, particularly for images near the top and bottom borders where vertical disparity is most pronounced.

Still another aberration may be caused

by a difference in magnification between right and left aspects. If one image is magnified in the horizontal direction more than the other, the subjective orientation of the composite image will be rotated about a vertical axis which passes through the point of fixation.[14] In such a case, Panum's area has the effect of rotating about its minor axis, decreasing the region where single vision is possible. It appears, therefore, that when magnification disparity exists, film registration should be more exact.

More recent work by Ogle shows that if the magnification disparity is only in the vertical direction, a similar subjective orientation rotation takes place, but in the opposite direction to that caused by horizontal magnification disparity.[15] Thus, as long as the lenses are astigmatically corrected, subjective rotations are cancelled out. However, the magnification disparity, albeit anastigmatic, has limitations outside of which cancellation of image rotation is ineffective. This limitation is given by Ogle as a 5% difference in magnification.[15] This value, according to Ellerbrook, is the same difference in magnification above which fusion no longer obtains.[8]

Such a large magnification disparity, however, does not normally occur, so it is concluded that the principal effects of a disparity in magnification between the two aspects are errors in apparent location, the necessity for vertical divergence of the eyes, and effects due to aniseikonia.

Disparity in Brightness

The use of separate films in stereography may result in a disparity of aspect brightness due principally to differences in film densities and in projection illuminants. The tolerance of such a disparity can be determined precisely only by actual tests. However, certain physiological effects of brightness disparity are known and are certainly indicative of the problems involved.

The eye is capable of discriminating brightness differences of only 1%,[12] but does this value set the limitation within which brightness disparity must be restricted? Murroughs[12] implies that brightness disparity should respect this limitation, yet Sir Charles Sherrington[2] has found that the light to one eye may be reduced 96% before binocular vision disappears. The problem of brightness disparity is not simply a restriction to thresholds, but is rather a determination of acceptable brightness differences between the two aspects. Such a problem can be resolved only by experimentation under normal 3-D projection conditions. Should one aspect become grossly more bright than the other, ocular dominance in favor of the brighter aspect will occur, whereas, as Davson points out,[7] a lesser disparity may instigate the appearance of luster. Tests will determine these thresholds.

A disparity in screen brightness will also have the effect of creating a disparity in the acuity of each eye, for it is known that, within the linear portion of the photopic illumination – visual acuity curve, effective for normal motion-picture viewing,

$$\text{Acuity} = K \log (\text{illumination}).^{16}$$

This difference in acuity between the two eyes due to a disparity in aspect brightness may be heightened by the present tendency to use aprons around the screen to yield a surround brightness. Since maximum acuity is achieved if the surround brightness is equal to the image brightness,[11] then, if the apron is made of some non-depolarizing material such as that used for the screen, the disparity in acuity will be due not only to a disparity in illumination but also to a disparity in the brightness of the surround.

An intentional disparity in brightness is one method, although not recommended, of increasing the subjective brightness of the composite image due to the effect that, as Sherrington[2] has investigated, the subjective summative effect of illuminations unequal in magnitude to each eye is somewhat higher than the mean of the two uniocular brightnesses. However, a better method of solving the acute problem of a decreased brightness in the 3-D film may lie in the use of optically active materials for polarizing the projected light. Such materials (e.g., quartz, Rochelle salt, camphor, turpentine, etc.) may effect a utilization of rejected polarized light. Research on this possibility should take into account the use of illuminants with spectral qualities different from those in present use. The employment of illuminants composed of two or more narrow wavelength bands may prove profitable as long as the additive effect of such bands yields an acceptable illuminant as regards color, while the locations of such bands in the spectrum are such that all or some of them can be rotated into the transmitted plane while any rejected light is normal to this plane. The choice of wavelengths should also consider the fact that acuity is a function of wavelength and that this function varies according to whether the illumination level is scotopic or photopic.[16]

Disparity in Color

The use of two separate films may lead to a disparity in color due to differences in filming, processing or projecting. The effect of such a disparity on perception is a function of differences in both wavelength and luminosity. Davson[7] gives the following three rules: (1) where colors are somewhat different and luminosity is essentially the same, color mixing is possible and conforms to the laws of monocular color mixing; (2) where colors are grossly different and luminosity is the same, color replacement occurs in which first one color, then the other, is perceived; (3) where colors are grossly different and luminosity is also different, ocular dominance occurs in favor of the longer wavelength and brighter aspect, but where these two factors are incompatible, that aspect effecting the stronger sensation will dominate.

In general, the right and left aspects will not differ greatly in either hue or brightness, and thus a mixing of both factors would be expected rather than replacement or dominance. However, the extent to which color disparity may exist without causing undesirable effects on the spectator must be determined specifically for 3-D conditions.

Differences in colors between the two aspects may also cause the light from one point in the field to be refracted differently than the light from its point pair due to the fact that the indices of refraction of the various fluids in the eye are functions of the wavelengths of the transmitted light. This chromatic aberration exists even if right and left aspects are identical. In the case of color disparity in the two aspects, no adverse effects due to ocular chromatic aberration are predicted as long as the disparity is not excessive, for in this case the image will fall within Panum's area.

Only a few of the factors of stereography have been related to the physiology of vision. No investigation has been made of the effect on the spectator of such considerations as the alternate presentation method of 3-D motion pictures, the anaglyph method, the transmission of a portion of the left aspect to the right eye, a disparity in the shutter phase angle wherever shutters are employed in the transmission system, binocular flicker frequency as against monocular, the reduction of depth perception due to reduction of light by the discriminating devices, the orthoptics of stereography, and other factors. For such considerations, and those that have been investigated, much experimental work must be done with specific motion-picture applications in mind.

DEFINITIONS OF MAJOR TERMS

Aspect: Either right or left view taken as a whole. Also known as a field.

Composite image: The resultant sensation experienced by a spectator by the proper viewing of disparate images.

Diplopia: The conscious sensation of seeing a single object as double.

Discriminating device: Any contrivance which allows each aspect to reach only the eye for which it is intended.

Disparate images: Two slightly different views of the same subject, one view being intended only for the left eye, the other only for the right.

Fixate: To direct one's eyes upon a point.

Point pairs: Right and left image points on the screen which, when fused by the spectator, appear as a single point in space.

Snellen acuity: A measure of the spectator's ability to see the separation between two points close together.

Stereography: The application of stereoscopy to photography.

Stereopsis: Perception of depth by the fusion of disparate images.

Stereoscopic cinematography: Motion-picture photography which allows the spectator to perceive depth.

Vernier acuity: A measure of the spectator's ability to see the offset from a line of a portion of that line.

Vertical divergence: The vertical angle between the optic paths to each eye.

Visual perception: The mental result of the influence of the psychological condition of the spectator upon a visual sensation.

Visual sensation: A primitive mental reaction to a stimulation of the retina by light waves.

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Auxiliary Multitrack Magnetic Sound Reproducer

By C. C. DAVIS and H. A. MANLEY

A four-track magnetic soundhead for reproducing CinemaScope films in theaters is described. The unit mounts readily between projector and upper film magazine and is film driven. To facilitate threading, the film sprocket is locked when the pressure pads are opened. A low natural-period Davis filtered drive insures high-quality film motion.

When Twentieth Century-Fox began the CinemaScope program, the Westrex Corporation was requested to design a special multichannel magnetic soundhead which would reproduce the four striped magnetic tracks on the composite release print employed in the CinemaScope presentation. The general requirements called for a unit, not to exceed 5 in. in height, to be mounted between the top of the picture projector and the upper magazine, capable of being installed with a minimum of effort. A 28-frame separation between picture and sound start marks was specified and provision was to be made in the soundhead for adjusting the length of the film path to accommodate different projectors employing varying film path lengths.

The CinemaScope program appears to be the first to utilize commercially a composite multitrack sound and picture release print. Figure 1 illustrates such a print and shows the location and dimensions of the four tracks. Tracks 1, 2 and 3 provide the three-channel stereophonic sound, while the fourth track is for special sound effects to be reproduced in the auditorium. It will be noted that the sprocket holes have been reduced in both width and height. The reduction in the width of the holes makes additional space across the film available for the multiple sound tracks.

The Westrex Stereophonic Reproducer has been designed to reproduce the four tracks of a CinemaScope release print without materially affecting the normal operation of theater equipment with standard release prints. For operation with standard release prints the equipment in the auxiliary head is by-passed and the film is threaded over two rollers and into the projector.

In considering the design of a film-pulling mechanism to meet the requirements, past experience indicated that three factors required special consideration. The first of these factors was obviously the successful scanning of the relatively small magnetic tracks adjacent to the sprocket holes. The solution was found to be an optimum combination

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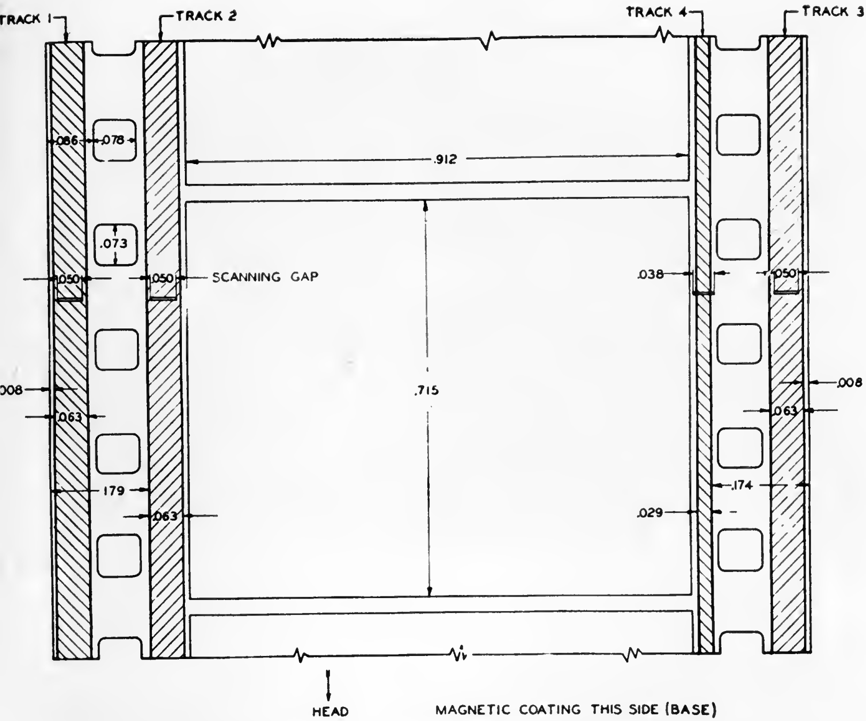

Fig. 1. Proposed sound-track standards for CinemaScope.

of film tension and angle of wrap about the heads which produced good head contact without excessive polygoning of the film, which occurs in increasing amounts in the area adjacent to the sprocket holes as the angle of bend of the film is increased.[1]

The second factor called for the design of a mechanical filter mechanism with an exceedingly low natural period in order to discriminate against as many as possible of the external disturbances which may arise in the projector mechanism or in the upper magazine. This in turn required an especially wide working range of the filter arms to avoid the possibility of their engaging their stops, due either to maladjustment or changes in coefficient of friction of the film coatings against the magnetic head.

The third factor arose from the small diameter of the impedance drums and bearings due to space limitations, and placed a severe requirement on the concentricity of these parts to avoid proportionately increased flutter at a 5.7-cycle rate to which the ear is quite sensitive. This condition was minimized by making each drum and shaft from a single piece of stainless steel and employing a precision-ground finish.

The reproducer is shown in front view in Fig. 2 and Fig. 3 is a rear view with the cover removed. The unit is readily installed by removing the upper magazine and fire trap, mounting the reproducer on the picture projector and mounting the magazine and fire trap on the reproducer. Figure 4 shows the unit mounted between the upper magazine and the picture projector. The

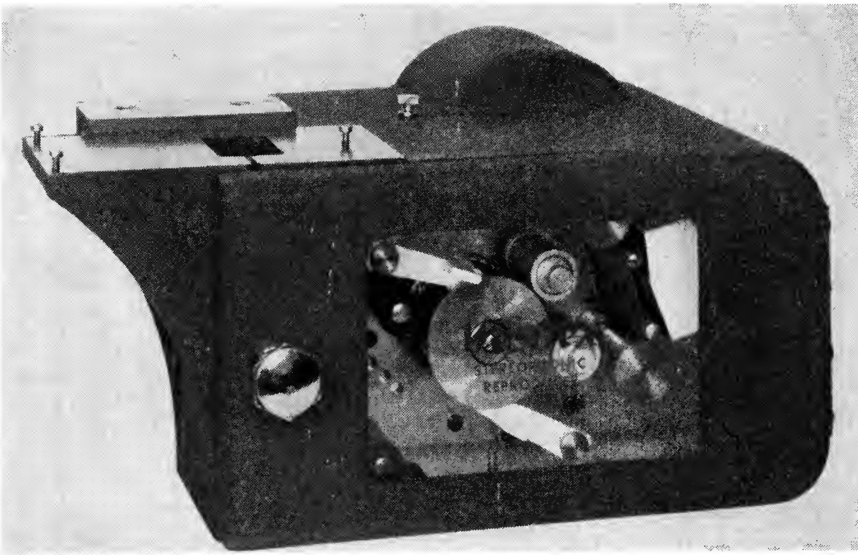

Fig. 2. Front view of reproducer.

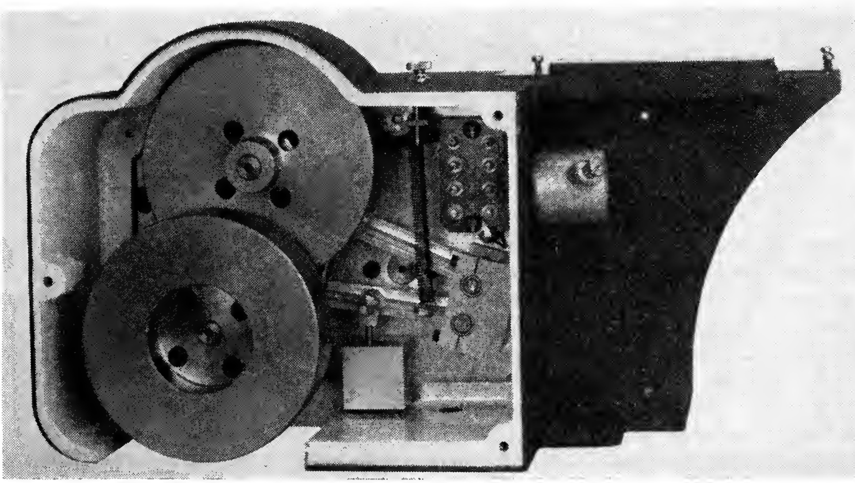

Fig. 3. Rear view of reproducer with cover removed.

upper magazine is mounted toward the left of the unit to provide a minimum of interference between it and the booth wall where steep angles of projection are encountered.

The reproducer consists of a cast housing provided with a front hinged door and a rear cover, and contains a film-motion filtering system and associated guide rollers, a four-track magnetic head and a terminal strip. The mechanical items are assembled on a base plate and can be taken out as a unit by first removing the two flywheels

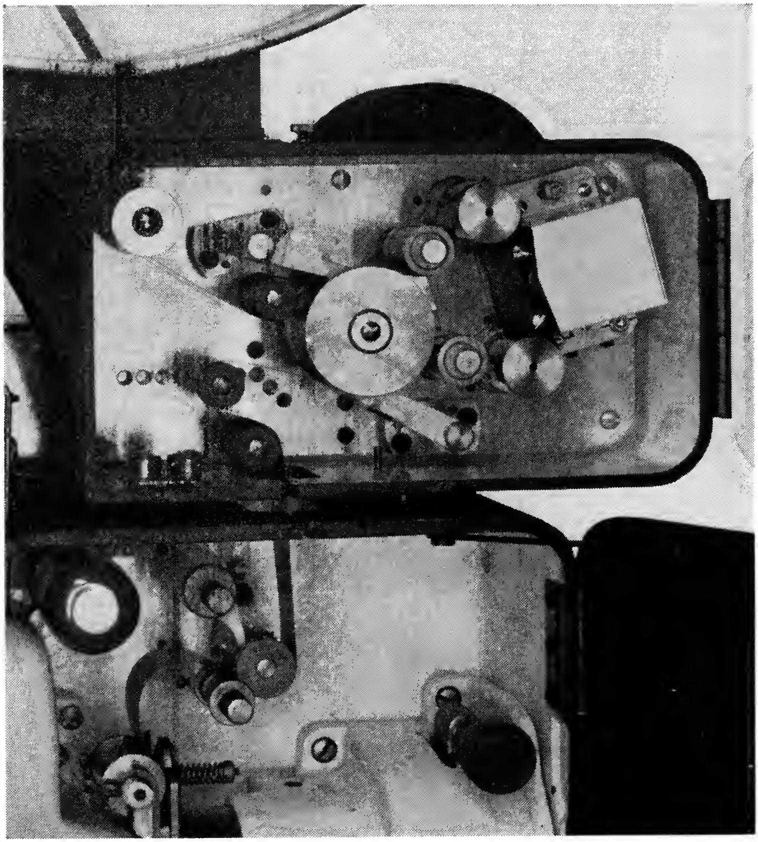

Fig. 4. Reproducer mounted between projector and upper magazine.

and unhooking a spring, and then releasing four corner mountings.

Figure 5 is a schematic representation of the base-plate assembly. It shows the path of CinemaScope film through the filter mechanism, over the magnetic head and around the idler rollers. It will be noted that the mechanism is similar to other magnetic film-pulling mechanisms using the Davis drive[2] with two impedance drums, except that in this instance the dual-purpose large sprocket is film driven, the film being driven by the upper film sprocket in the picture projector. Since the length of film path from the picture aperture to the top of the housing varies in different makes of projectors, one idler-roller position has been made adjustable and is set at the time of installation to compensate for this variable and to provide the correct separation of 28 frames between picture and sound.

The filter-arm assembly is similar to those used on previously designed machines except that in this case the filter rollers are without flanges, the film being guided by flanges on the film sprocket. Threading is aided by holes through two targets on the filter arms which become concentric when the correct length of film is threaded. The

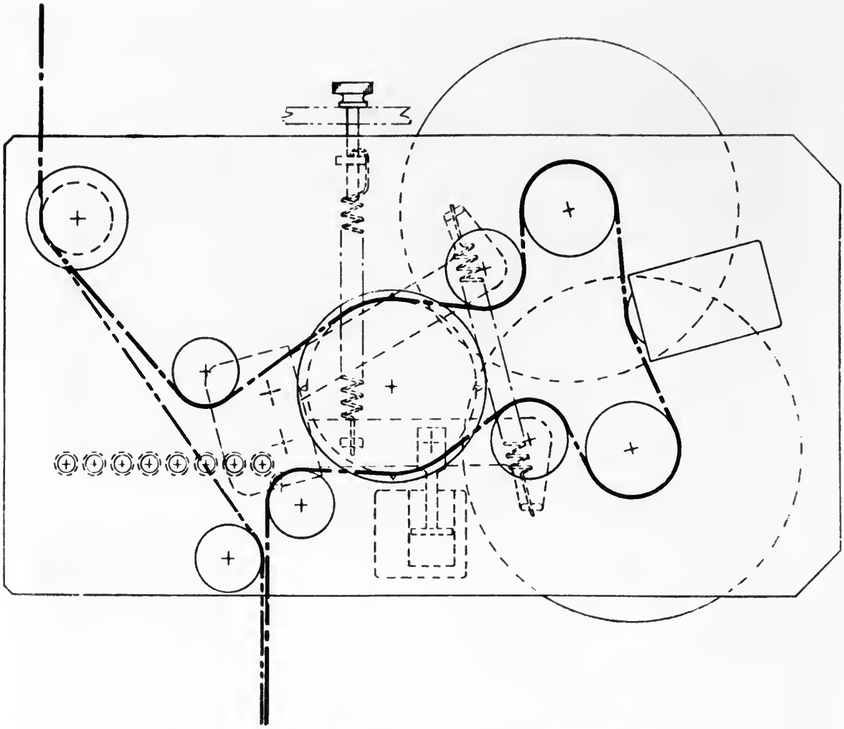

Fig. 5. Schematic representation of base-plate assembly.

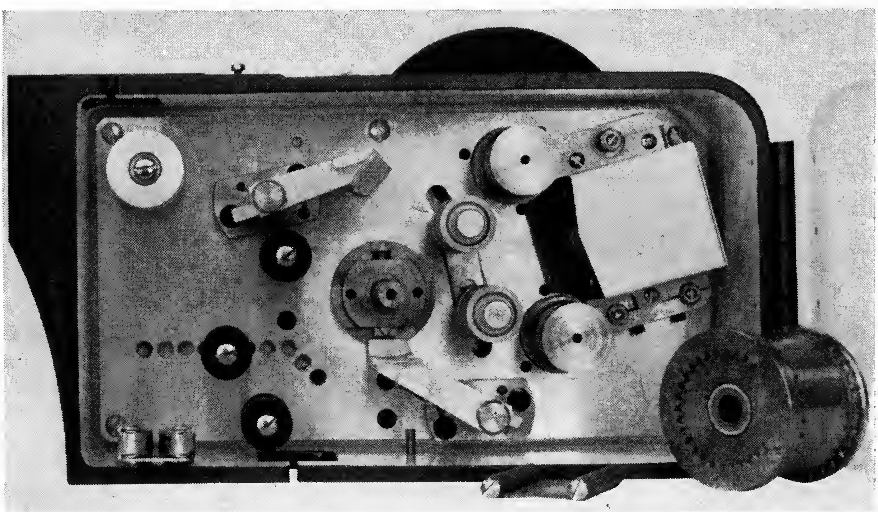

Fig. 6. View of reproducer showing method of locking sprocket.

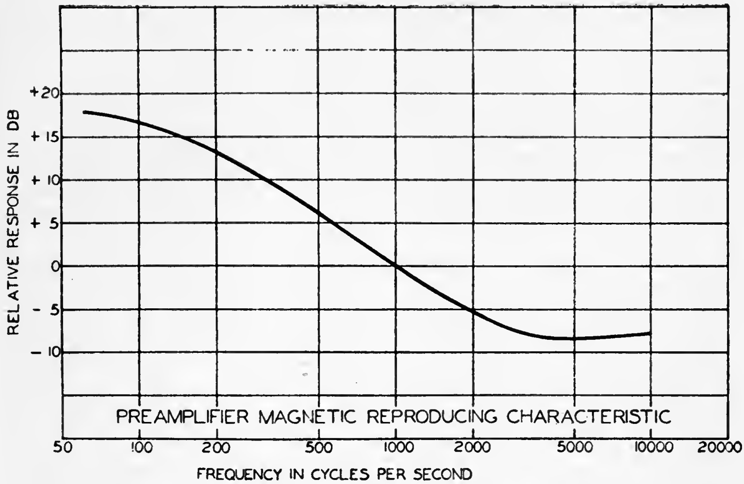

Fig. 7. Frequency characteristic of preamplifier.

front surface of the rear target is painted red, adjacent to the target, so that the red shows through the hole when an incorrect length of film is threaded. The filter arms are capable of an unusually long excursion to provide a wider range of operation of the filter system.

Two similar pad arms prevent the film from running off the sprocket. If the sprocket were always free to rotate, it would present a somewhat awkward situation during film threading. However, means have been provided for locking the sprocket when either pad arm is open. The method by which this is accomplished may be seen by reference to Fig. 6 which shows the reproducer with the sprocket removed. The inside face of the sprocket contains a gear with internal teeth, and two pawls are mounted within the sprocket-shaft assembly which is fixed in position. A common spring forces the pawls radially outward so that they engage the teeth of the internal gear and lock the sprocket at two points. An extension on each pad arm depresses one pawl and disengages it from the gear teeth when the pad arm is closed. Therefore, when both pad arms are closed at the completion of film threading, the sprocket is free to be driven by the film. The angle of engagement of the pawls has been selected so that while they hold the sprocket sufficiently rigid for threading, they will slip at a tension considerably below the breaking point of the film. This insures against a film breakage should the operator fail to close the pad arms before starting the motor. All film-contacting surfaces have been undercut in the picture area to avoid possible abrasion of either film base or emulsion surface. The rotating elements in the filter system are ball-bearing mounted, except the sprocket which has a specially lubricated Oilite bearing. The three idler rollers are made of graphite-impregnated nylon and require no lubrication. The guide roller in the upper lefthand corner has an Oilite bearing. This results in a mechanism that requires no lubrication.

The magnetic-head assembly consists of three 50-mil heads and one 38-mil head located on a common axis and mounted on a base plate. The spacing of the head scanning centerlines is fixed at the time of assembly in accordance with the CinemaScope proposed standards for magnetic sound reproducing equipment. The heads are shielded against stray magnetic fields by a mu-metal case and shield. The heads contact the film at a point midway between the two drums, thus maintaining a symmetrical relationship of film wrap about the gap regardless of variations in film compliance. Means are provided for adjusting the heads as a unit to insure correct azimuth, centering of the gap and track position.

An amplifier assembly, consisting of four preamplifiers mounted in a metal box, has been designed to provide a signal output from the four magnetic heads at a nominal level of −12 dbm for the stereophonic tracks and −18 dbm for the effects track. The frequency response characteristic of the amplifiers is shown in Fig. 7. This characteristic, together with that resulting from scanning with heads having 0.5-mil gaps, gives an overall reproducing characteristic which is in accordance with the standard proposed by the Motion Picture Research Council. The resulting overall frequency characteristic is flat from 50 to 8000 cycles/sec. within the limits of the proposed standard.

The auxiliary soundhead described in this paper offers a simple and relatively inexpensive means of reproducing CinemaScope stereophonic sound films with a high degree of fidelity. When mounted on a projector in good operating condition, low-frequency flutter components are not greater than 0.03%, while the total root-mean-square value of flutter is within the 0.15% value which is the generally accepted requirement for theater equipment. The guiding of the film at the sprocket reduces film weave to a minimum which is particularly desirable with the use of narrow tracks. Maintenance requirements have been reduced to a minimum. There is no contact with the film in the picture area, no lubrication is required, the mechanism stabilizes well within the allotted starting time and complete facilities are provided for alignment should occasion arise for the ultimate replacement of the magnetic head.

References

1. Loren L. Ryder and Bruce H. Denny, "Magnetic sound track placement," *Jour. SMPTE, 58:* 119–136, Feb. 1952.
2. C. C. Davis, "An improved film-drive mechanism," *Jour. SMPE, 46:* 454–464, June 1946.

Film-Pulled, Theater-Type, Magnetic Sound Reproducer for Use With Multitrack Films

By J. D. PHYFE and C. E. HITTLE

This paper describes a new type of sound reproducer which attaches to the top of standard 35mm theater motion-picture projectors. The unit permits elective playing of conventional photographic sound films by means of the usual projector-soundhead combination or magnetic tracks by means of the attachment. Sound reproduction using the attachment is of excellent quality and falls within Research Council recommendations for magnetic-track reproduction.

Methods of motion-picture presentation have undergone some drastic changes since the more or less static period of the thirties and forties. Now the public may choose their type of theater entertainment from among several including the old 2-D, the new 3-D, and the enlarged-screen types. The new types have one feature in common, the use of multiple sound channels entailing the use of film having a multiplicity of soundtracks. Most of the new film systems are using separate magnetic soundtrack type of films for the sound system. A system recently developed by Twentieth Century-Fox Film Studios, however, is a single-film type including both picture and multiple soundtracks on one 35mm film. In this film system, multiple stripes of magnetic coating are applied to the picture film after processing, and then the individual soundtracks are recorded on the magnetic striping with the sound lagging the picture by 28 frames. The magnetic stripes are located as shown in Fig. 1 with the striping applied to the base side of the film.

A new type of magnetic sound reproducer is required to reproduce the sound of such composite picture-multisoundtrack film. Since the sound lags the picture by 28 frames, the reproducer must be mounted on top of the projector to satisfy the picture-to-sound displacement requirements.

A sound reproducer designed specifically for the new composite-type film is shown mounted on a projector in Fig. 2. Available mounting space on the top of the various makes and models of projectors currently in use in theaters influenced to some extent the size and shape of the unit. Compactness of the

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(This paper was received Oct. 6, 1953.)

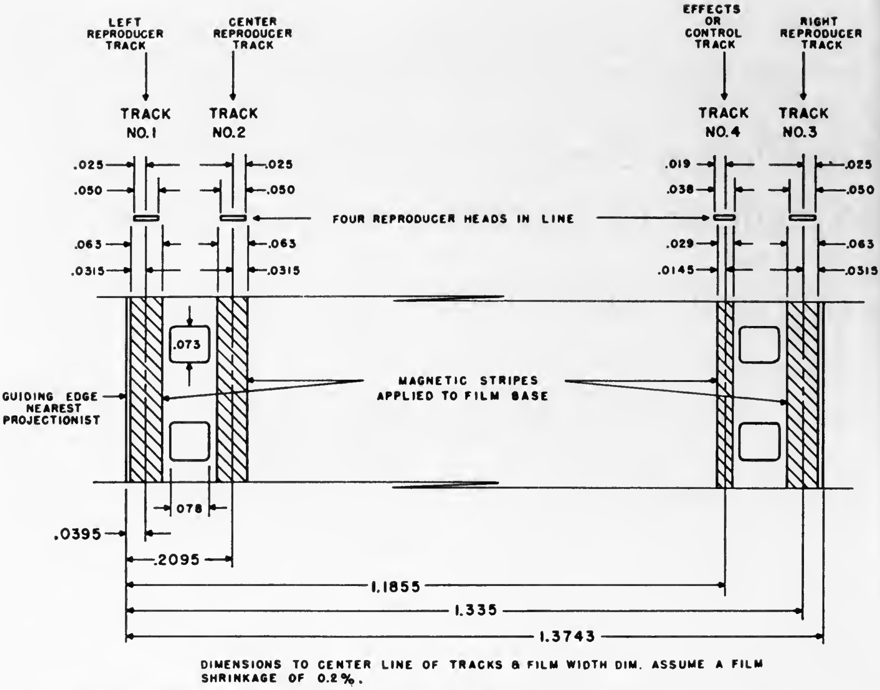

Fig. 1. Proposed magnetic-track standards for CinemaScope-type film.

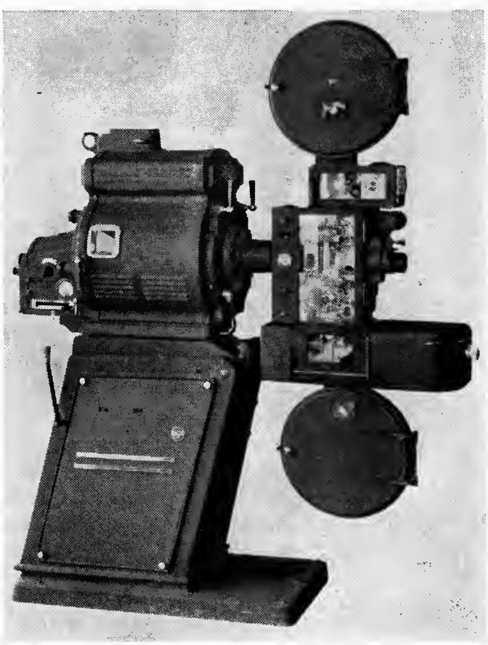

Fig. 2. Magnetic soundhead mounted on RCA projector.

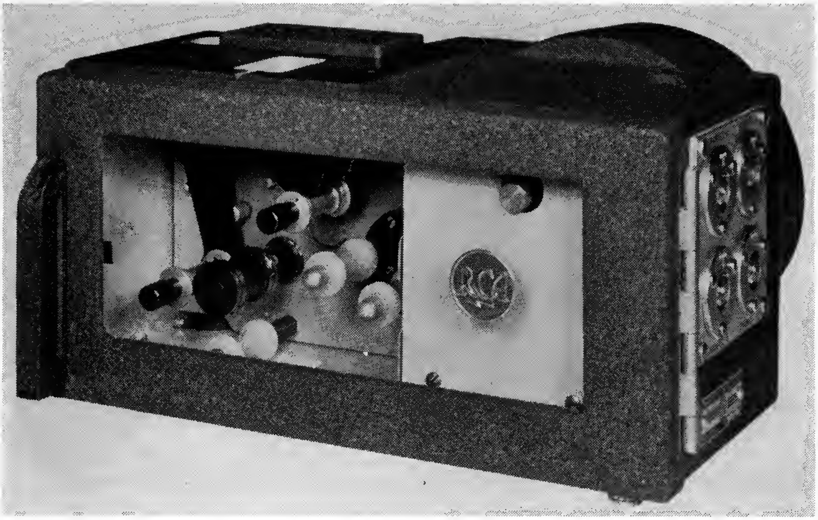

Fig. 3. Magnetic soundhead.

reproducer and simplification of the mechanism was made possible through a unique operational feature. The film is pulled through the unit by the picture projector, thus eliminating the need for a separate interlock drive motor or drive gearing from the projector.

Some idea of the compactness of the unit may be obtained from Fig. 3. In this view may be seen the door, mechanism housing, rear cover and part of the mechanism-panel assembly visible through the glass window of the door. The first three parts mentioned above plus the mechanism panel are of cast aluminum construction. The exterior of the unit is finished in an umber gray wrinkle. A light-colored finish is used on the inside surfaces to provide better visibility for threading.

The door is hinged and is attached to the housing at the right side in accordance with standard projector and soundhead procedure. The rear cover is attached by screws since it seldom need be removed. The mechanism-panel assembly is supported in the housing by means of four rubber isolation mounts with adequate clearance being provided between the edges of the panel and the interior of the housing to eliminate any metal-to-metal contact between the panel and housing. Likewise, no parts affixed to the panel, other than the isolation mounts, are in contact with any parts fastened to the housing. This is an important feature of the design since experience has proven that vibration of the magnitude, which may be present with the majority of motion-picture projectors, can adversely affect the film motion at the region of film contact with the magnetic head, giving rise to excessive high-frequency flutter.

Figure 4 shows the soundhead with the door open. Mounted on the mechanism panel may be seen the upper and lower film sprockets, pad rollers, sprung-flange guide roller, pressure roller, impedance drum, magnetic-head assembly, a sprung double-roller assembly, three fixed-position rollers, which assist in formation of the correct film path through the unit, and part of the shield of high-permeability metal

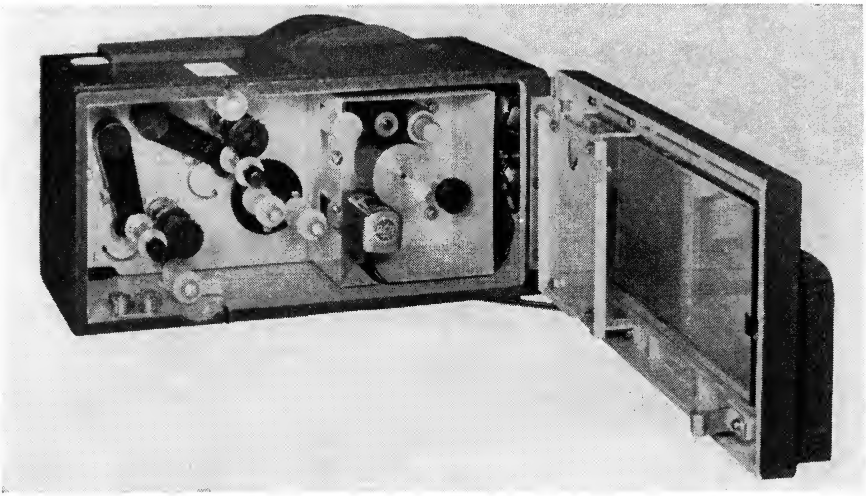

Fig. 4. Magnetic soundhead, door open.

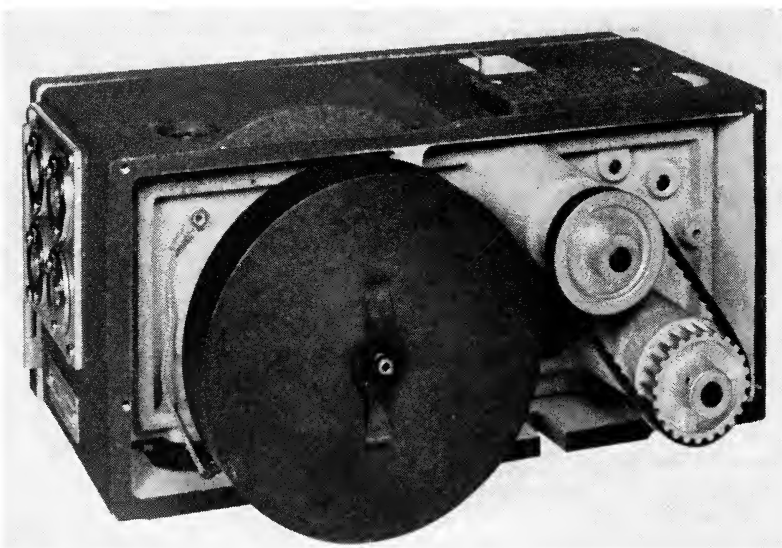

Fig. 5. Magnetic soundhead, rear cover removed.

which encloses the area in which the magnetic head is located. (The front cover of the shield is attached to the rear face of the door to facilitate access for film threading.) The two sprockets and associated rollers are offset vertically with respect to each other, to permit film threading downward from the feed magazine to the projector, by-passing the magnetic-head section of the soundhead, when using standard photographic soundtrack type of picture film. If film guiding through the soundhead is desired, the film may be threaded around the sprockets and pad rollers only.

The upper sprocket is driven from the lower sprocket by means of timing-belt type of pulleys mounted on the rear of the sprocket shafts and a connecting precision-molded, tooth-type rubber belt shown in Fig. 5. This drive gives results comparable to a precision gear drive at considerably less cost. During operation with the film threaded for magnetic sound reproduction, as the film is pulled into the projector by the projector feed sprocket, the downward film pull causes the lower sprocket of the magnetic soundhead to rotate. The upper or feed sprocket is driven at the same speed as the lower sprocket since the belt drive is as positive as a gear drive and the pulley ratio is one to one. Both sprockets are of the 16-tooth type with tooth width and tooth pitch selected specifically for the new composite-type film and the new functional usage of the sprockets. The primary reason for incorporating two 16-tooth sprockets in the design rather than one 32-tooth sprocket is directly related to the type of filter system used and the desirability of keeping the height of the soundhead to a minimum consistent with good design practice. Use of the two sprockets simplifies film threading since a natural film wrap is afforded about the sprockets for the desired film path.

The filter system is a film-pulled, drum-type, soft-loop system. Drum-shaft assembly includes a solid flywheel mounted on the rear of the drum shaft. The flywheel is protected from accidental contact by operating personnel during operation of the unit by the rear cover of the soundhead. The double-roller assembly mounted between the magnetic-head assembly and lower sprocket comprises a second portion of the filter system. The two rollers are mounted on a common arm which in turn is mounted to a pivot shaft at a point midway between the two roller shafts. The assembly is biased by means of a clock-type spring enclosed in a cavity at the rear of the pivot-shaft housing. Damping is afforded by use of silicone grease in the spring enclosure and shaft bearing. The primary soft or compliance film loop is formed between the feed sprocket and drum. (Had a single 32-tooth sprocket been used, additional height would have been necessary to provide clearance between the soft loop and the film passing around the rollers of the double-roller assembly.) Most of the random irregularities in film motion on the feed side of the soundhead are absorbed in the compliance loop ahead of the drum.

Tests were made on models of both tight-loop and soft-loop filter systems. Film motion was comparable on the two systems when used with a projector having good feed-sprocket motion and a feed magazine producing uniform drag or holdback. However, when projector feed-sprocket motion and feed-magazine drag were not uniform, a condition likely to be encountered in the field, film motion obtained with the soft-loop filter system was superior to that obtained with the tight-loop system.

An improved method of construction for multiple heads* has been incorporated in the design of the magnetic-head assembly shown in Fig. 6. The four heads are contained within a single, precision-cast housing. The face of each half cluster is lapped on a precision flat which inherently makes all the gaps in true alignment when the half clusters are assembled together. The azimuth, head height and track location are accurately adjusted with respect to the mounting surface during assembly. After all assembly and final lapping operations are completed, the

* Kurt Singer and Michael Rettinger, "Multiple-track magnetic heads," *Jour. SMPTE, 61:* 390–394, Sept. 1953.

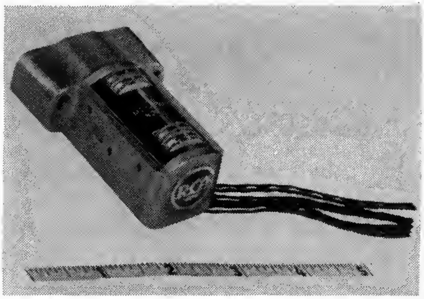

Fig. 6. RCA 4-track magnetic-head assembly.

heads are inspected for conformity to design specifications for azimuth, head position, inductance and uniformity of output.

The head assembly is mounted in the soundhead adjacent to the drum so that the film contacts the head immediately after leaving the drum. Angle of contact of film on head is approximately thirty degrees. This degree of contact assures minimum amplitude modulation and is beneficial in prolonging useful head life. The head location is at the portion of the film path where best film motion exists.

Flutter content is less than 0.15% rms when measured with a test film having a flutter content of less than 0.1% rms. Amplitude modulation is less than 1 db. Uniformity of output is within $1\frac{1}{2}$ db at 8000 cycles and 1 db at 1000 cycles.

Since the size and configuration of the top surface of various projectors currently in use vary, it was impractical to design the soundhead for universal mounting. Instead, the unit was designed for mounting on a projector having a flat top surface of adequate area, and adapters have been designed and will be available to permit mounting the soundhead on the various other projectors now in use.

This magnetic reproducer will permit the same projector soundhead now reproducing optical tracks to reproduce multichannel or stereophonic sound without the need of a separate interlocked magnetic dummy. By combining the ability to reproduce either photographic or magnetic soundtracks into one projector-reproducer assembly, considerable savings may be realized over the double-film systems. Also, no additional floor space is required in the theater projection rooms. Sound reproduction using the attachment is of excellent quality and is within Research Council recommendations for magnetic-track reproduction.

Four-Track Magnetic Theater Sound Reproducer for Composite Films

By S. W. ATHEY, WILLY BORBERG and R. A. WHITE

A four-track, magnetic sound reproducer which mounts between the upper magazine and the picture mechanism of a standard theater projector is described. Features include: minimum increase in overall projector height, no interference with normal projector operation and excellent film motion. The use of this unit for the initial experimental recording work which produced the first composite CinemaScope film demonstrations is also described.

In the early part of 1953, the Twentieth Century-Fox Film Corp. demonstrated the wide-screen motion-picture process now known as CinemaScope to motion-picture industry groups, and asked the equipment suppliers of the industry to attempt the development of methods for carrying a stereophonic sound record on the same release film with the picture.

In response to this request the equipment described here was developed in two overlapping stages: (1) the development of a practical method of recording and reproducing stereophonic sound on a single 35mm film, which would at the same time leave the maximum amount of space available for the CinemaScope picture; and (2) the commercial development of theater equipment for reproducing such a stereophonic sound record.

Twentieth Century-Fox originally proposed that sound be carried on three 50-mil magnetic stripes applied adjacent to the sprocket holes of standard 35mm film. This proposal was modified in many ways during the months that followed, but eventually became the basis of the final commercial-release version of CinemaScope film. The sprocket holes were narrowed, and the space made available by this change was used to add a fourth "effects" or "audience surround" track and to widen the three main tracks to 63 mils; otherwise the original proposal was retained. The final release-print standards were established by Twentieth Century-Fox on the basis of information and reports of progress transmitted to them by this company and others working simultaneously on the same problem. A drawing of the release-print picture and sound-track locations

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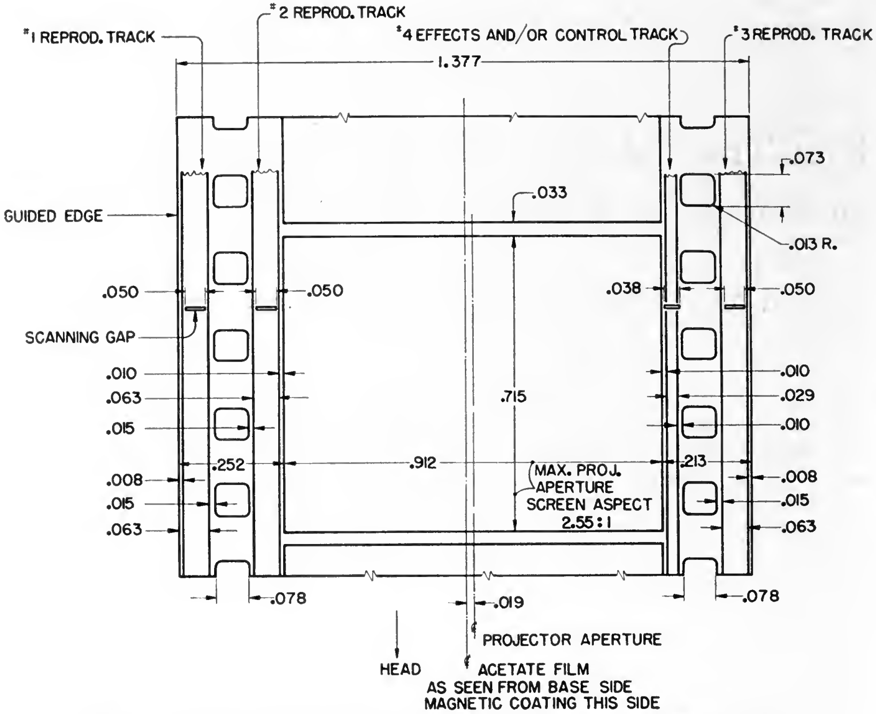


Fig. 1. Proposed release-print standards for CinemaScope sound track and projector aperture.

as presently used by Twentieth Century-Fox is shown in Fig. 1.

General Precision Laboratory Inc., made the first single-film stereophonic recordings of Twentieth Century-Fox demonstration material with a production prototype of the soundhead described below four months after the presentation of the problem. Electronic recording facilities were of a breadboard type, assembled partly from components lent by Twentieth Century-Fox, and recordings were made on a projector with the arc operating to provide a continuous check on synchronization. Although this was scarcely a "studio" method of operation, the recordings so produced were of commercial quality and made it clear that the final proposal would make a commercially successful product.

The Simplex Single-Film Stereophonic Sound System for the reproduction of composite stereophonic sound film contains three major new units which are added to the basic Simplex Stereophonic Sound System. These are: the magnetic soundhead, the preamplifier assembly, and the power-supply switcher assembly.

Magnetic Soundhead

The magnetic soundhead, shown in Fig. 2, is mounted on top of the projector head, as shown in Fig. 3. This departure from the conventional location of the photographic sound pickup is not new, having been employed in some early sound-on-film proposals. However, since a different synchronizing distance between picture and sound was inevitable for magnetic tracks, a separation of 28 frames behind the picture was

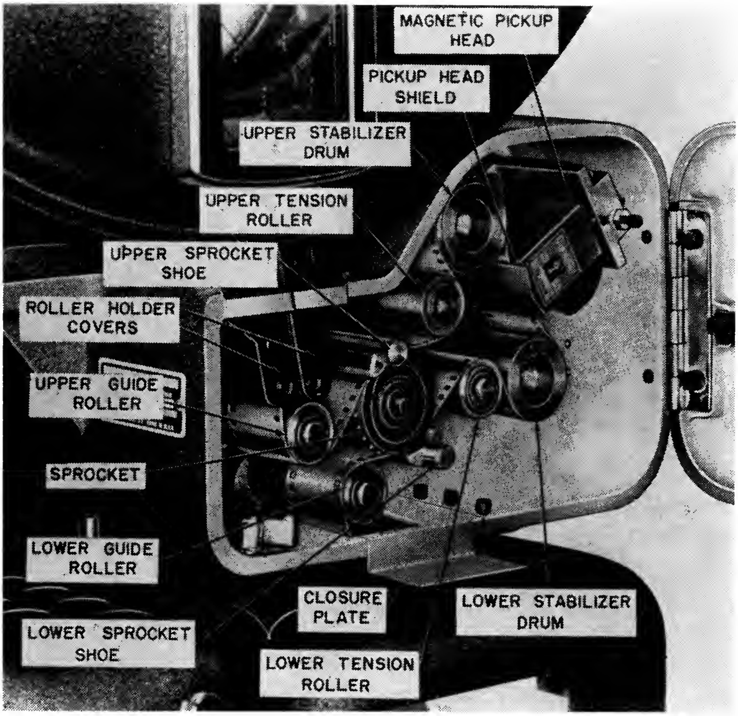


Fig. 2. Simplex four-track magnetic soundhead.

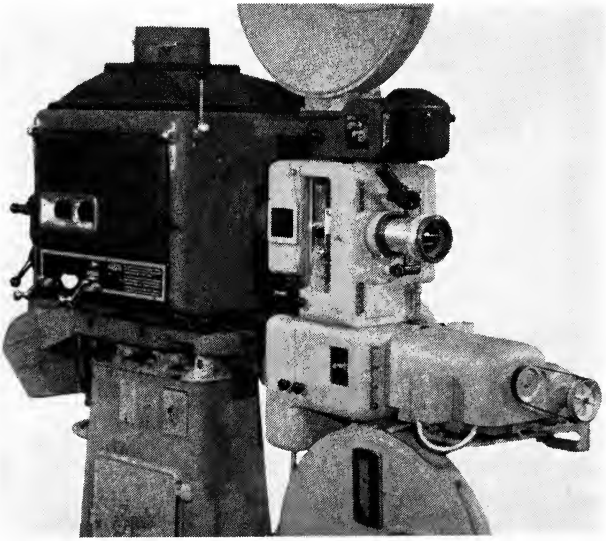


Fig. 3. Simplex four-track magnetic soundhead mounted on a Simplex XL Projector.

agreed upon so as to accommodate the various types of projectors in service.

Some of the advantages of the top-mounted soundhead may be listed briefly here:

(1) The photographic soundhead may be left unmodified. This carries the advantages that:

(a) The photographic sound performance need not be affected.

(b) A magnetic-photographic soundhead must have compromise performance, because the magnetic sound stabilizer must operate in the presence of head friction.

(c) A photographic soundhead cannot have many parts added to it without becoming excessively overcrowded.

(d) Any system which converts existing photographic soundheads for magnetic sound must provide for the conversion of an impractically large number of soundheads of all types.

(2) The magnetic-hum-field-sensitive sound mechanism can be moved far from the strong hum fields of motors and selsyns.

(3) The threading of the soundhead is done at convenient eye level.

(4) The film at the new magnetic scanning point has not been subject to the momentary frame deformation or buckling caused by the absorption of heat energy while in the picture gate.

The Simplex Magnetic soundhead adds only 4 in. to the overall projector height and does not affect the normal operation of the projector. Films with photographic sound tracks are threaded to bypass the magnetic pickup system and films with magnetic sound tracks may be threaded to bypass the photographic sound scanning system. The magnetic soundhead is entirely film-driven and uses a tight-loop stabilizing system to provide extremely uniform film motion. One function of the single sprocket is to maintain the length (and thereby the tension) in the tight loop. The filmpath is shown in Fig. 2, passing over two tension rollers and two stabilizing drums on whose shafts are mounted flywheels. To insure proper side guiding of the film, the upper stabilizer drum (directly ahead of the magnetic pickup head) is flanged. A tension spring beyond the pivots of the tension roller arms maintains the film tension, and a centering spring attached to one of the arms maintains the rollers centered.

A rotary viscous damper employing a sector of a cylinder rotating in a silicone fluid inside a cylindrical drum provides damping for the filter system. The damping is applied directly to one of the filter roller arms in order to avoid the backlash inherent in any mechanical linkage. The natural period of the filter is about $\frac{1}{3}$ of a cycle, and excellent flutter performance results.

Because the single sprocket acts passively, the filter system is well isolated from external disturbances. Such disturbances are "passed on" to the pulling sprocket by the soundhead sprocket, and the filter system exists in a sort of backwater or eddy off to one side of the main filmpath.

All parts of the soundhead which contact the magnetic coating on the film (except the magnetic pickup head) are of nonmagnetic material, including the stabilizer drums and shafts, which are of stainless steel.

The magnetic pickup head is mounted on a bracket which is held on a slide by a spring and a lock screw. This slide permits lateral adjustment of the head relative to the film, with a stop screw and lock nut for holding the correct location. Three set screws in the base of the magnetic head permit azimuth and tip adjustment of the head relative to the bracket, with the three head-mounting screws locking this adjustment.

An early form of an annealed mu-metal front shield, formed over a cold rolled steel form is shown in these

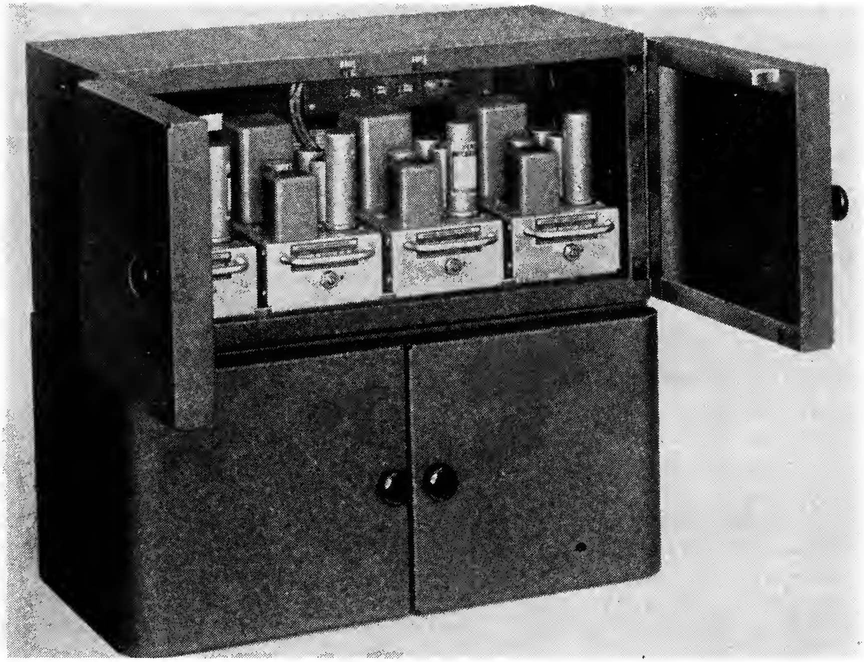


Fig. 4. Preamplifier cases for Simplex four-track magnetic sound system, showing plug-in preamplifiers.

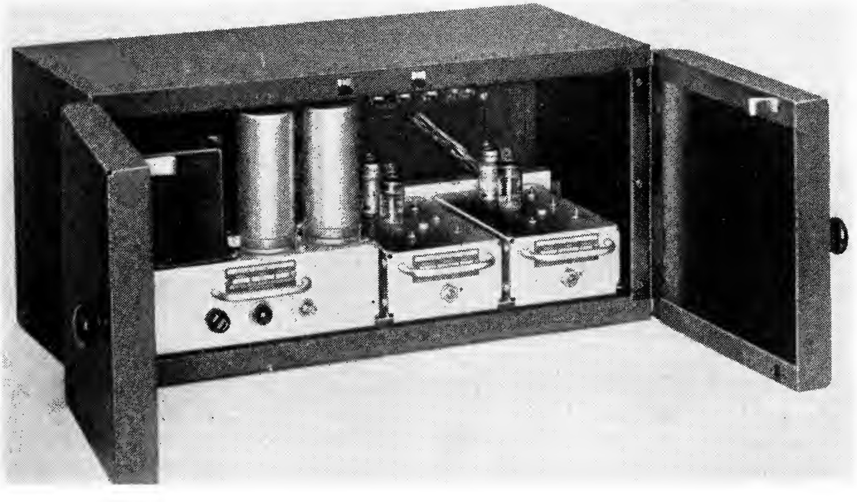


Fig. 5. Power-supply switcher case for Simplex four-track magnetic sound system, showing one plug-in power supply and two plug-in effects switchers.

pictures. The present form of this shield permits quick removal of the shield for head cleaning and degaussing. For severe hum fields, a box shield which slips over the magnetic head and is held by spring tension is provided.

The magnetic pickup head is a Brush type BK1544-S1237, manufactured by the Brush Electronics Co. to reproduce film conforming to specifications supplied by Twentieth Century-Fox. The connections for the individual track heads and a ground are brought out to a Cannon type DA-15P plug mounted on the side of the head, and a mating plug and shielded harness carry the connections to a barrier terminal strip in the connection box on the front of the soundhead.

Threading the soundhead is simple. The correct loop length is automatically obtained by threading tightly with the sprocket pad shoes open, since a pin on one pad shoe operating toggle limits the movement of one of the tension arms. Closing the pad shoe releases the tension arm and permits it to perform its filtering function.

Preamplifier and Power-Supply Switcher Assemblies

This equipment is mounted in wall mounting cases of two types, but identical external appearance (Figs. 4 and 5). The preamplifier case mounts four plug-in preamplifiers, and the power-supply switcher case mounts one power-supply and two "effects" switchers. The electronic assembly for two projectors consists of two preamplifier cases mounting four preamplifiers for each projector and one power-supply switcher case. For a three-projector installation, one preamplifier case and one power-supply case must be added. Under these conditions, the second power-supply case contains one power-supply and one effects switcher, and a removable (not plug-in) dummy load for the unused part of the power supply.

Cannon type DPB twelve-pin plugs with twinax input connections are used for the preamplifiers, and I.P.C. type F-10A and M-10A connectors are used for the power-supply and effects switchers. Terminal blocks in the back of the mounting cases are connected by harnesses to the plug strips which are mounted on a channel strip. A power-supply case and a preamplifier case differ only in these plug-harness assemblies and the reversal of the mounting blocks for the plug channels.

The preamplifier is of conventional design, employing a 5879 and a 12AT7 tube. The 5879 is connected as a pentode, and is followed by an RC equalizing circuit. The 12AT7 is connected as a cascaded triode amplifier, with feedback over the two stages. A potentiometer in the feedback network provides an approximately 6-db gain adjustment. The input transformer is a UTC HA100X, connected for a nominal 50-ohm input impedance, and the output transformer is a UTC A-25 with plate current in the primary, the output being connected for a 500-ohm output.

For purposes of gain measurement, the head-source impedance is considered to be nominally 50 ohms. The dummy source which is actually used for measurement consists of a 6-ohm generator in series with a magnetic pickup head. For calibration, this source is terminated in 50 ohms and the power into this resistor is considered to be the signal delivered to a nominal 50-ohm load.

With the gain control at maximum, the gain of the preamplifier at 1000 cycles/sec is 75 db. At maximum gain, input short-circuited, the output noise is −45 dbm. The output signal at 1000 cycles/sec, from a 50-mil track modulated to 3% distortion is +7 dbm and for a 29-mil track at 5% distortion, +1 dbm. The distortion at +8 dbm output is less than 0.75% above 300 cycles/sec. At low frequencies, the distortion rises to 1.2% at 50 cycles/sec. The recording pre-emphasis of 6.5 db at 50 cycles/sec, however, assures that the maximum level at 50 cycles/sec for 3% recorded distortion on the film, plays back at +0.5 dbm at the preamplifier output. At this level, the output distortion of the preamplifier is less than 0.5%.

The power supply is conventional and not regulated, with a two-section choke input filter. The d-c filament supply for the preamplifier delivers 600 ma at 19 v with a single-condenser filter providing 0.5 v peak-to-peak ripple. The filaments of the 5879 and 12AT7 are connected in series, with the 12 v connection for the 12AT7. Two filament supplies are provided in each power supply, each for four preamplifiers. 6.3 v a-c is also provided for the effects-switcher filaments.

As the preamplifiers are unplugged, successive sections of a series resistor string are unshorted to improve the regulation of the filament supplies.

The effects switchers perform the function of connecting the outputs of the effects-track preamplifiers to the power amplifiers driving the audience surround loudspeakers when a 12-kc control tone is recorded on the effects track and disconnecting these preamplifiers when this tone is absent. The purpose of this arrangement is to remove distracting hiss, crackling or crosstalk from the audience surround speakers when no effects signal is present on the effects track.

The switchers employ a tuned circuit to select the 12-kc control tone and apply it to the grid of one half of a 12AT7 tube which acts as a tuned amplifier for this tone. The tone is rectified in a voltage doubler and applied to the grid of the other half of the 12AT7 to control a plate circuit relay which controls the connection between the effects power amplifier and the effects-track preamplifier. A further tuned circuit discriminates against the control tone in the sound path.

The outputs of the effects switchers are connected in parallel, since the 12-kc control tones perform automatic changeover for this channel. The outputs of the three stereophonic channels for each projector are fed to Simplex AM-202 or AM-203 changeover boxes. The output of the effects switchers are fed to a Simplex AM-207 system selector box, which selects the route for optical and effects sound for single- or double-film stereophonic or optical sound. These units are parts of the basic Simplex Stereophonic Sound System which is not described here.

The Simplex Single-Film Stereophonic Sound System which has been described has the following minimum performance specifications:

- System signal-to-noise ratio — 52 db
- System frequency response (from CinemaScope multifrequency test film) — ±1 db 40–12,000 cycles/sec
- System distortion at 3% recorded distortion level on test film — less than 0.75% total harmonics
- Flutter (from CinemaScope flutter test film) — less than 0.2% one-sided peak.

The authors wish particularly to thank the following persons for their invaluable contributions in the development of the equipment described here: R. W. Burfeind, F. N. Gillette, W. D. Hay, R. L. Kenngott, and D. B. Shaw, all of General Precision Laboratory Inc.

Equipment for Stereophonic Sound Reproduction—Panel Discussion

JOHN K. HILLIARD, Moderator

E. K. Carver (Eastman Kodak Co.): What tension is required over the magnetic head, especially in the two cases where a combination sprocket is used? How great is the tension on the film in that isolated portion?

John G. Frayne (Westrex Corp.): It's approximately 400 g, in the closed film loop.

Skipwith W. Athey (General Precision Laboratory): I believe the actual tension in the film is of the order of 8 oz and the force against the head is of the order of 3 to 4 oz.

Dr. Carver: The thing that's bothering me, really, is the difficulty in running a combination sprocket, which is not suitable either for holdback or feed with a high tension.

Dr. Frayne: There's no problem if the sprocket is properly designed. In the Davis Drive, we have always recommended a sprocket-tooth base that nearly fills the sprocket hole in the film. This minimizes the "crossover" effect where the tension in the filtered film loop exceeds or becomes less than that in the external film paths. This crossover usually results in high flutter content at this point in the film running. In the Westrex CinemaScope head we use a base tooth dimension of 70 mils. We would like to use a base of 73 mils and completely fill the sprocket hole, but the film shrinkage prevents this. We refer to this type of tooth colloquially as the "fat-tooth sprocket."

Mr. Athey: I think we can confirm exactly that same effect. The sprocket form is of crucial importance. (We prefer to avoid the use of a full-fitting tooth, however, because the reproducing equipment must operate properly with shrunk film, as opposed to the essentially unshrunk film with which recording equipment operates.) In the early development we did not have sprockets of the proper pitch diameter and our flutter performance was therefore not very good. However, with sprockets of optimum pitch diameter, flutter due to tooth ripple is essentially eliminated over a normal range of film shrinkage. (The most prevalent causes of the "crossover" trouble are bent reel flanges, nonuniform friction of the feed-spindle brake, and sticky fire-valve rollers.) With properly adjusted equipment, the crossover phenomenon can be prevented throughout the run of the reel, and flutter from this source can be eliminated.

W. G. Hill (Ansco, Binghamton): I'd like to clear up just one point about this fat-tooth sprocket. Dr. Frayne speaks of a 0.70 base. May I ask what that is? What is 0.70?

Dr. Frayne: The sprocket-tooth base is 0.070 in.

Mr. Hill: So that dimension is intended to fit the narrow way of the hole?

Dr. Frayne: Right. Lateral positioning is not critical.

Mr. Hill: May I ask, then, about how many teeth in contact do you use?

Dr. Frayne: I don't recall exactly.

Mr. Hill: It doesn't allow very much for shrinkage.

Dr. Frayne: No, but there is no problem with film with normal shrinkage. Perhaps some other members of the Panel would like to comment on this.

This panel discussion was held on October 6, 1953, at the Society's Convention at New York.

Willy Borberg (General Precision Laboratory): About three or four teeth are in contact in our unit.

Dr. Frayne: I believe that in the Westrex design there are fourth teeth in contact with the film.

Loren L. Ryder (Paramount Pictures Corp.): I should like to ask Dr. Carver, if I may, what type of sprocket has been used in the life-test information recently published with respect to the new sprocket holes and sprocket teeth; and the second part of this question is to the Panel: What life tests have been made with the fat-tooth sprocket as applied to this new technique?

Dr. Carver: We have run life tests on only the intermittent sprockets. We have not yet been able to get hold of any soundheads to determine the effect of the soundheads on film life. The narrow-tooth sprocket which we first used was ground down from the standard tooth width — it happened to be an 0.955-in. sprocket with a standard transverse pitch. That did not give quite as good fit as the special sprockets would. With sprockets of 0.955-in. diameter, that is a sprocket that is oversize relative to the pitch by about 0.8%, we got about four to six times the life that we expect on ordinary 0.935-in. sprockets, such as have been used so much in the past as intermittent sprockets. That is, we found that the increase in the diameter of the sprocket, leading to an increase in pitch and to a correct sprocket-tooth film-pitch relationship, increased the life of the film a very great deal. In fact, without the magnetic stripes on, which increased the friction, we got almost ten times the life. Now, we recommend 0.953 in. because it seemed that the 0.955 in. was going a little far, in case the film should shrink more and with a 953, after we got some sprockets specially made, we got equally good or better life.

Mr. Ryder: There is another question pertaining to these sprockets, and that is: If the new sprocket tooth and the new sprocket-size diameter improve the life of the film with the new sprocket-hole width, how much more does it improve the life of the old sprocket-hole size if we use the new sprocket tooth and new diameter?

Dr. Carver: Mr. Loomis is here and he can correct me if I'm wrong. I think that the old sprocket hole runs a little bit better with all sprocket teeth than the smaller sprocket hole. What I'm saying really is that if you have the right size sprocket, you're way out ahead of where you've been in the past anyhow. The small amount that the smaller sprocket hole takes away from your life, is a very small fraction of what you gain by the increased size sprocket.

John Maurer (J. A. Maurer, Inc.): I'm impressed by the fact that we seem to be moving forward in practically every aspect of sound quality, except with respect to flutter. This is a partial continuation of correspondence which I have had with our Sound Committee Chairman about test films. I would like to ask the Panel — anyone who is in a position to answer — what is the frequency spectrum of this flutter and why is it so hard to get the flutter in the recording below about 0.1%?

Dr. Frayne: In magnetic recording, as I believe I have pointed out in previous papers, we have not yet been able to get as low flutter content at high-frequency rates as in photographic. On the low-frequency end there's no problem, because we use the same film-pulling mechanism, the same filter system, but in magnetic recording we have to pull the film over a solid head. If you remember the old straight gates in photographic recording in 1928, they were not very good either. When we went to drum scanning, we had no frictional contact and we succeeded in getting very excellent flutter performance on photographic film. Now recording on magnetic shows an increased high-frequency flutter content over photographic. However, it's not entirely harmful, because the flutter rates are very high. On a typical flutter chart on magnetic you'll get excellent flutter performance until you get up in the 96-cycle region and then you may find values of the order of 0.10% and 0.15%. On a very good job, it may be as low as 0.05%. Then in the band, say, between 100 cycles and 200 cycles, the flutter may jump some more. In general, I would say that magnetic recording is inferior to photographic in the high-frequency flutter rates.

Mr. Maurer: Do I infer correctly that the real trouble is longitudinal vibration of the film past the head?

Dr. Frayne: Apparently so, yes.

Edward Schmidt (*Reeves Soundcraft Corp., Springdale, Conn.*): I should like to point out that this question of high-frequency flutter affects not only the application of magnetic film in the motion-picture industry, but other industries as well. I was thinking of the telemetering applications of FM work and there is considerable work being done by all manufacturers of magnetic products to reduce or cut down on the head-scrape — that's about the best term that we've come up with so far. Perhaps it's coefficient of friction of the coating to the magnetic head.

Dr. Frayne: I think that we did find that some manufacturers put out what they call a lubricated magnetic coating which does improve the high-frequency flutter performance.

George Lewin (*Signal Corps Pictorial Center*): Can anyone advise whether there is any individual adjustment on these multiple heads for head contact with the film?

Mr. Athey: With the Brush head, which we are presently using, there is no way in which the individual contact can be adjusted, other than that the entire head can be tipped. It may be that as a result of wear, this individual adjustment may become desirable. At the present time, the attitude that we have taken (and I believe the other manufacturers, too) is that if the filter system is properly aligned so that the tension is equalized between the two sides of the film and the contact surface of the head is flat, then for all practical purposes the tension and head contact are consistent across the film. It has been very difficult to catch up with the theaters on life tests. In other words, in 24 hr you can't gain more than about 10 hr over a given theater. Our knowledge of the effect of lack of individual track adjustment as it affects the life of multiple-track, composite film is, I'm afraid, rather elementary. The present head is potted in plastic and it would be somewhat of a problem to do individual adjustment of, say, track 2 relative to track 1 and track 3.

Mr. Lewin: I assume, then, that the adjustment for reproduction must be a lot less critical than for recording, because I know that in recording we probably would miss terrifically the absence of an individual adjustment for each head, since I don't think the film ever lies completely flat.

Mr. Athey: I think I can use this as an occasion to make the point that in the beginning of this development there was evidence that there was amplitude modulation as high as 50%, 50 mils away from a sprocket hole. This evidence was based on the fact that a 200- or 250-mil track had been laid down and then played back with a 50-mil sampling head. Under our present CinemaScope conditions the track is laid down with a 50-, or eventually, a 60-mil head (I believe it's still a 50-mil now, isn't it?). The tension is localized in the individual area that you are concerned with. It's not the same process as attempting to keep the film absolutely flat across the 200- or 250-mil head, at part of which the contact may be poor. When you simply try to keep it flat over a 50-mil contact area, the problem does not seem to be as great. At any rate, this is our estimate from the results we have had. For example, when we had pieces of film which had had the edge wrinkled so that there was a definite kink, after a recording had been laid down, we could not hear this kink going through the machine. If the film were erased and an attempt were made to re-record, we just got a large hole in the sound, actually before and after this kink, as the film bounced clear of the head. The contact is, of course, more important on recording, because of loss of bias and the like, than on playback. I believe that the localized tension in the narrow track eliminates many of the difficulties that may occur with wider tracks, where the film is relatively stiffer.

Mr. Lewin: My question wasn't so much whether the contact was uniform across the width of one head, but whether the film is going to lie flat enough so that when you got good contact in one head, you have good contact on the others, especially the ones in the middle.

Mr. Athey: Would you estimate that the contact was going to be poor on the edge or in the middle?

Mr. Lewin: Well, I would assume that if you have good contact on the two outside tracks, that the track inside, the one that's in the conventional photographic sound-track position, might tend to dish inward and have poor contact.

Mr. Athey: We do not have any proper evidence, but it is my impression that the situation is exactly backwards from that. However, perhaps some of the others have some experience with it.

Dr. Frayne: I was going to add that the only problem that we've had so far is with so-called tonying of the film.* If you get a film with a bad tony in it, then, of course, you get a very bad contact, but if the film is in normal condition then there's no particular problem.

Walter T. Selsted (Ampex, Redwood City, Calif. This statement read by Charles H. Wirth, Ampex Corp., New York District Office): "As most of you know, Ampex Corp. has recently developed studio and field recording equipment for the Magna Theatre Corporation. Recently we have developed a complete line of theater sound reproducing equipment designed specifically for the reproduction of CinemaScope pictures.

"During our work on these projects, we made extensive investigation of the relationship which pre-emphasis and post-emphasis bear in respect to weighted signal-to-noise ratio and distortion. The pre-emphasis and post-emphasis characteristics established through the NARTB were based on studies made relating sound-source energy distribution with saturation characteristics of magnetic recording media. The studies of energy distribution made by Bell Telephone Laboratories in 1929 were recently repeated by Ampex Corp., which found excellent agreement. Recently repeated tests confirm that the NARTB standard characteristics are an optimum compromise between unweighted signal-to-noise ratio and high-frequency tape saturation. Great improvement can be realized in the listening quality of narrow-track magnetic recordings now being introduced for motion-picture sound, if the record pre- and post-emphasis at high frequencies are reconsidered, placing more importance on weighted signal-to-noise ratio and putting less importance on occasional high-frequency compression due to magnetic saturation. In design of the equipment for Magna Theatre Corp., we appreciably altered the pre-emphasis characteristics in the recorder with a resultant improvement in weighted signal-to-noise ratio of better than 10 db. Recently, studies we have made indicate that, using similar techniques and suitably choosing the recording material, an improvement of approximately 16 db can be achieved on a weighted basis. These improvements in signal-to-noise ratio are primarily in the upper end of the audio spectrum where tube and tape hiss are the objectionable quality of which the listener is immediately conscious. The techniques we have used indicate an improvement of at least 7 db throughout the rest of the spectrum."

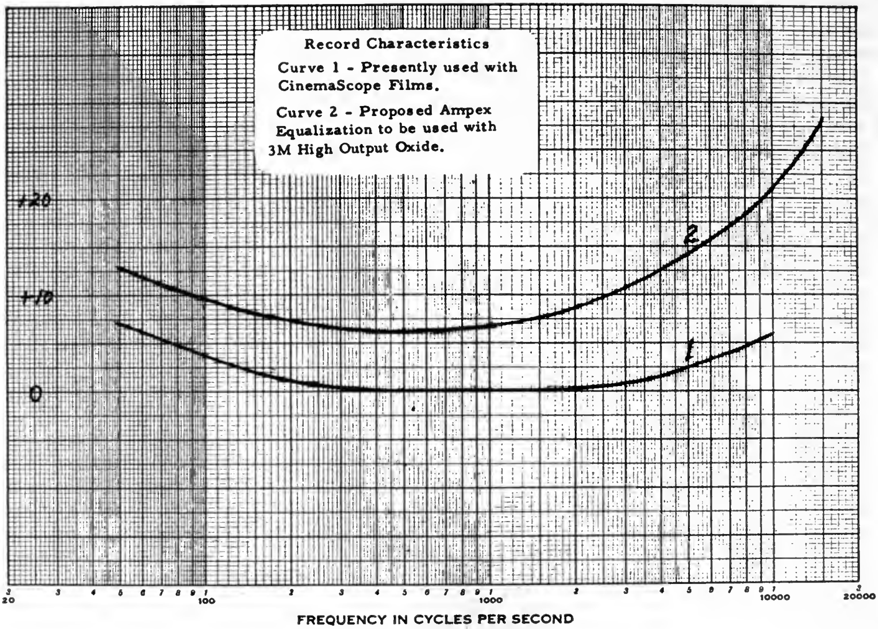
Ampex has had such good results with these recently developed changes in equalization that we should like at this time to propose that the Ampex equalization characteristics be accepted as an industry standard as well as a standard adopted by the Society of Motion Picture and Television Engineers.

With your permission, I should like the opportunity to show you the two slides I have brought with me on which the equalization curves which Ampex proposes are shown. The first slide shows the record amplifier equalization characteristic. The one presently used by the motion-picture industry is shown on Curve 1, the only exception being that the low-frequency pre-emphasis used with CinemaScope films has been added (Slide 1). Curve 2 shows the increase in high-frequency pre-emphasis which we find is not only acceptable but highly desirable, and the 6-db spread between the two at low frequencies merely illustrates the approximate increase in output from the tape realizable by means of the new oxide developed by Minnesota Mining.

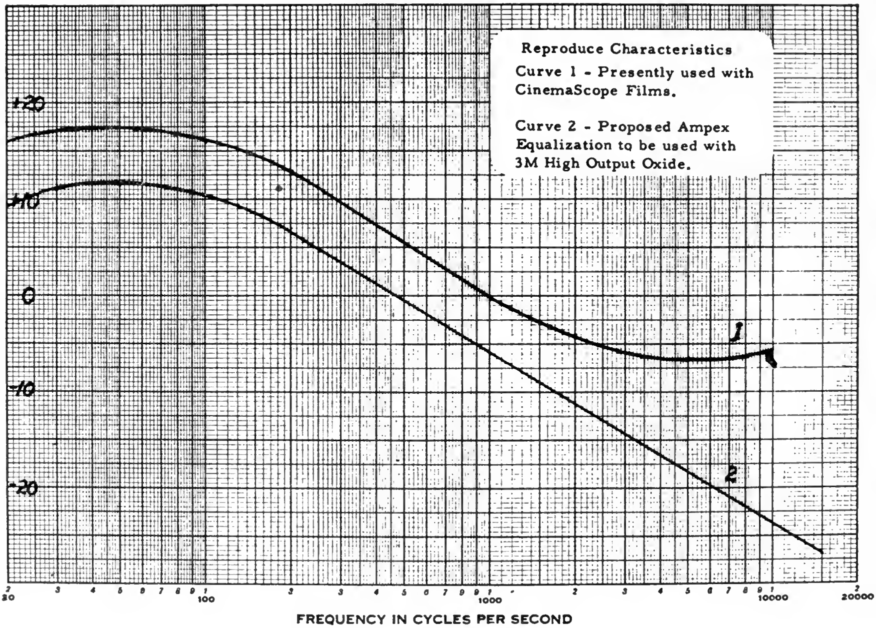
Slide 2 shows the necessary playback equalization curves to complement the record characteristics in each of the two former cases. As you will notice, the spread between the two curves beyond 1000 cycles increases quite materially. Since it is in this region where the most audible hiss occurs, the improvement in signal-to-noise ratio at any particular frequency is approximately equal to the spread between these two curves.

We wish to recommend these Ampex

* Fluting or waviness along the edge of the film, usually on one edge only but sometimes on both. See *Common Causes of Damage to 35mm Release Prints*, Motion Picture Film Dept., Eastman Kodak Co., Rochester 4, N.Y.



Slide 1



Slide 2

equalization curves to the industry as a standard for motion-picture sound recording.

I would like, at this time, to make a motion that a copy of this statement be referred to the Magnetic Recording Subcommittee for evaluation and adoption.

Mr. Hilliard: There's no motion necessary. It will be submitted and I can assure you that there will be a very lively discussion on this matter, because pre- and post-equilization are not new with any part of the motion-picture industry and you can anticipate that it will be fully discussed tomorrow in the Standards Committee. The reason for reading this communication at this time is so that those members who are interested and wish to discuss it are certainly invited and urged to attend the Standards meeting tomorrow and go over this particular item as well as many of the other things that are to be discussed.

Malcolm G. Townsley (Bell & Howell Co.): The Subcommittee on Magnetic in the morning is a good place for that.

Mr. Hilliard: Yes.

Richard Norton (Warner Pathe News): I'd like to ask you gentlemen, jointly, if a definite standard has been arrived at for the separation of the picture gate and the actual soundhead. Is it standard between all your different soundheads or does it vary from one manufacturer to the other? Would that preclude the possibility of using a Super Simplex head with an RCA Stereophonic Reproducer? And likewise other combinations, or would a particular soundhead be required to complement the same manufacturer's picture head?

Mr. Athey: Obviously we designed our soundhead to fit directly on the most expensive and best Simplex projector. It is, however, also designed for adaptation to other projectors and I believe that is true of the rest of the people here. I believe that the Ampex device is designed for the Simplex XL, can be adapted very simply to the Simplex E7, and with adaptor plates, to other projectors. In addition to projector adaptation, there's another little problem which is adaptation to 18-in. and 25-in. magazines of various manufacturers, but I believe that in one way or another all the manufacturers have managed to cope with this problem.

William Youngs (International Motion Pictures, Washington): Is this system compatible with 3-D? In other words, would the addition of the stripes on the film cause an increase in thickness, which in turn would cause film distortions in matched prints? In particular, would a theater be still required to install a magnetic dummy for reproduction of stereophonic sound on 3-D, or could this same thing be worked on that?

Mr. Ryder: I believe this procedure is not even compatible with standard 2-D. The system that has here been suggested is based upon a picture placement and picture centerline which are different from the standard. If a standard picture were to be projected on the equipment when it is lined up for this system, the centerline of the picture would not align with the centerline of the screen. This is a serious problem.

Mr. Athey: Do you mean by that, that with the higher accuracy required of 3-D pictures for minimum eyestrain and the like, the mechanical changes caused by the stripes might cause some defect in projection which would affect the 3-D effect?

Mr. Youngs: Yes, I do. You know, the air getting in between the layers of the film, and the resulting warpage on it and your film going in and out, further aggravation caused by the high-intensity lights and sometimes film stored on trucks just overnight, or in film vaults when the prints are not in use, absorbs moisture.

Mr. Athey: Of course, we do not have very extensive experience with these things. I would, however, suggest, that the amount of light that is being poured through CinemaScope films to get a bright picture on a big screen is enough to cause as much distortion, if it is going to occur, as the fight for light with 3-D. It is my belief that the critical nature of the anamorphic lens system is such that you can tolerate very little more, and perhaps less, distortion in the CinemaScope process than in 3-D before film flutter or out-of-focus becomes very serious. This is strictly a personal observation from many hours spent in a number of projection booths in the last few weeks.

E. S. Carpenter (Escar Motion Picture, Cleveland): Have there been experiments in lacquer-coating the film or the sound stripe?

Mr. Schmidt: I rather doubt that any normal lacquer coating over the sound track would be useful in any respect. Magnetic recording depends on intimate head contact for optimum results, and anything that you put on the top of the track will interfere with your head contact.

Mr. Carpenter: How much tolerance do you think is allowed?

Mr. Schmidt: Zero.

Mauro Zambuto (*Italian Films Export*): Have any tests been made to find out exactly what the performance is of the old-fashioned sprocket-hole film on the new type of sprockets?

Dr. Carver: In the very beginning, I believe that Twentieth Century-Fox realized that any new sprockets they made would have to run at least as well on film with standard perforations as the old sprockets. It turns out that if you do not increase the diameter of the sprocket you get slightly worse results, but if you use an intermittent sprocket with a diameter of 0.953 in. you get at least five times as good results as far as wear and tear on the film goes as you would with a 0.935-in. sprocket such as is ordinarily used. You also get better results than if you use a 0.943-in. which is the ASA standard. The 0.953-in. sprocket more than compensates for any decrease in wear you might get with the narrower teeth. Does that answer your question?

Mr. Zambuto: Thank you. It does as far as wear and tear are concerned. But what about the stabilization of the film drive? For instance, you don't have any variation in film positioning both as far as sound track and picture are concerned?

Dr. Carver: I can't answer on the sound track, but I can see no reason why we should. I think I'll have to ask Mr. Loomis to say if he has noticed any increased weave on the picture with the narrower teeth? I think he has not.

H. A. Loomis (*Eastman Kodak Co.*): We haven't projected any pictures on the wear tests, so we really don't know.

B. C. Passman (*International Projector Corp.*): Mr. Athey has described briefly the effects-switching system used in the GPL system. I wonder if Dr. Frayne or Mr. Phyfe would care to comment on their systems.

Mr. Phyfe: We have a suppressor system now in operation in our labs in Camden and we have it in production as well; we have used the circuit originally suggested by Twentieth Century-Fox and find it very satisfactory.

Dr. Frayne: I can state that we had a working breadboard model about two weeks ago and will probably be in production shortly. Incidently, we have been having some debate with Lorin Grignon as to the feasibility of changing over — instead of having the 12-kc on at the same time as the signal, to have instead the 12-kc on during the silent period. It just reverses the operation of the circuit. That was still under debate when I left.

Mr. Hilliard: I'd like to comment on that last remark from Dr. Frayne. We have had a great many changes back and forth here and the system which we are presently making — that's International Projector and General Precision Laboratory — is operating, I believe satisfactorily with the 12-kc on during the sound effects. It seems undesirable to make a further change unless it's necessary.

Edward S. Seeley (*Altec Service Corp.*): Was it Dr. Frayne's proposal that, although *The Robe* has been recorded with 12-kc present when effects are to be reproduced, thereafter succeeding pictures should be recorded differently and that the equipment now in use, and there is quite a little of it and it is going in very fast, should all be replaced with equipment that will work in the opposite direction?

Dr. Frayne: It's a very simple change to make in the field.

Mr. Athey: Maintaining the 12-kc during the effects sound is certainly, in one sense the hard way to do it. It is my impression from the demonstration recordings that we make for Fox that the modulation noise from the 12-kc, even though the 12-kc is not audible, is a disturbing factor. Unfortunately, and this is just my guess from not very exact results, as the frequency gets higher, any errors in recording contact become more impressive in their effect on the signal. What we get if we do not have perfect contact is a modulated 12-kc modulation noise. However, there are great system simplifications made possible by the present arrangement. As a matter of fact we do not change over our fourth track at all from projector to projector. This, as far as we are concerned, is a great simplification. We have had several phone calls suggesting turning it around the other way. We have, unfortunately, also had expressions of the idea that maybe the 12-kc control signal would turn on the left speakers, a 14-kc control signal would turn on the middle speakers, the lack of a control signal would turn on the right speakers and something like 13-kc would make the whole system dead. I trust that we will have a little time to develop this before we make any decision.

Mr. Hilliard: Do any of you have any recommendations on a higher frequency that might be used for this control or some other frequency that you think could switch it, other than the immediate area around 12-kc?

Mr. Athey: No.

Dr. Frarne: I thought, perhaps, that you might be interested in how the prints were made on this system of recording. We were asked by Twentieth Century-Fox to develop what was called a magnetic printer. What we have supplied and what is being used to turn out the prints for *The Robe* consists of a master four-track reproducer, which reproduces from four master magnetic tracks. Each track is 150 mils wide on fully coated film. We had to design a special four-track head for this operation. This reproducer is equipped with complete reproducing facilities including equalization so that we get a 1:1 transfer as far as frequency characteristic is concerned. Then the output from this reproducer is fed to a battery of five quadruple-track recorders, running at normal speed and these recorders are in cabinet-type racks, or in a special cabinet, which contains complete recording and reproducing transmission facilities.

The film runs at standard speed, at 90 ft/min. It was originally considered to run the film at a higher speed, but because of the desirability of monitoring to permit the operator to monitor at will at any one track in any one machine, it was decided to retain the normal speed at 90 ft/min. These five machines are tied together in interlock, using a composite synchronous interlock type of motor which does not require any distributor. Any one machine can be run individually for test purposes on the sync-motor basis or any group of machines can be tied together by simply throwing a switch on each machine to run in interlock. The five recorders will eventually be equipped with 60-mil heads to lay down a 60-mil track. Due to shortage of such heads, the present prints on *The Robe* are being made with 50-mil tracks, which is the same as the reproducing. Obviously, from the weave standpoint, it's desirable to have the recorder track wider than the scanning head in reproduction. This system is working very well. There are other bottlenecks in reproduction, but not in the printing operation.

Mr. Lewin: I've noticed in making distortion measurements on magnetic recordings that when you get up into the high frequencies you often get distortions that don't seem to show up on the meters, but your ear tells you they're there. Apparently they are heterodynes that are set up between the high frequency and the bias frequency, or possibly for some other reason; but for that reason I feel that you have to be very cautious about increasing the amount of high-frequency boost in your recording, because even though the frequency response might look as though you made an improvement and the noise measurement might tell you that you got less noise, you still might have a poor recording, because it just doesn't sound as clean on the high frequencies due to this heterodyning effect.

Mr. Hilliard: This problem has been considered at great length for several years, both from a radio-channel and recording-studio standpoint. The NARTB curve referred to 16 db of pre-equalization and then, in examining the frequency contents of the Academy Research Council test reel, it was found that the 100% modulation point in speech was repeated more often in the range between 2000 and 6000 than any other region; and so I think that it behooves us to approach the degree of equalization that is proposed in a very cautious manner, because of the nearness of the microphone in the case of recording and the situation of sound effects and other frequencies that are well up in the spectrum of increased amplitude if you use the equalization characteristic.

Mr. Zambuto: Sometimes measures of increased signal-to-noise ratio which can be made on certain frequencies will not tell the whole story, particularly when you consider recording of speech. This is due to the effect you were just mentioning, that is, spectral distribution of energy in speech. I happen to have made some experiments on this and we had some rather interesting results, particularly regarding the spectral distribution of speech in different languages. For instance, in Italian we found that we have more middle frequencies around 2500 to 4500 than you have in English, the latter being richer in higher frequencies. Therefore, it often is the experience of Italian mixers that if you boost that particular range of middle frequencies, you have to pull down your average level in order not to overmodulate, and therefore you reach 100% modulation at a lower power level; as a result you lower your expected signal-to-noise ratio considerably. I think this effect should be kept in mind in evaluating the advantages of a new standard.

Mr. Hilliard: It has been my opinion, and I think it is being confirmed currently, that the amount of equalization proposed is as drastic as was used in the NARTB curve and it has gradually been dropped. The AES disk recording and reproducing curve indicates the trend, and I know from experience in motion-picture sound recording that this amount of equalization was tried originally and has been dropped because of the fact that you would penalize yourself in overall level or overload, or a combination of both.

Mr. Ryder: At Paramount, from the inception of magnetic recording, we have used pre-equalization in the amount of between 10 or 12 db at 8000 cycles. We have had good success recording that way and I should say far less trouble than we had in other recording activity. At Ryder Services, when I do outside work I comply with the standards of the industry, I do not use pre-equalization. So I have one plant, namely Paramount, with pre-equalization; another plant, Ryder Services, without pre-equalization, and believe me, I prefer the pre-equalization. I'm on the side of Ampex.

If there is varying contact in recording and reproduction, the effect is not as bothersome in my work with pre-equalization as in my work without pre-equalization. I am very much in favor of pre- and post-equalization, especially as we diminish the width of the sound track.

Dr. Frayne: I believe since we have supplied some equipment to Paramount Studios I can elaborate a little on Mr. Ryder's remarks. I'm quite sure that Mr. Ryder continued to use the same pre- and post-equalization on magnetic that Paramount has used on photographic recording and which we had supplied to him. That equalization is not nearly so drastic as Ampex proposes. It flattens off, as a matter of fact, around 6500 cycles, and at least as originally supplied it does not exceed 12 db. Now, also bear in mind that the experience at Paramount is with original recording, not on release. As far as I know, Paramount has not released any film with that degree of pre-equalization, because the theaters couldn't play it back. You'll notice that the Research Council is proposing some pre-equalization. The recording characteristic was not shown here today, but it suggests about 3 to 4 db pre-equalization at 8000 cycles only so that we can get a fairly flat overall response with the proposed reproduction characteristic of the preamplifier.

Mr. Ryder: We have actually tried this out in the theaters, and the first magnetic installation for theater reproduction at the Chinese in Hollywood was made for Paramount and under our supervision. The Chinese happens to be one of the key theaters in Hollywood. We have done a fair amount of experimenting in this field, and we still think that we're right, but this is the type of thing that makes for good horse racing and we like that, too.

Dr. Frayne: I'd like to add, that in the Chinese installation they were 200-mil tracks which have a slight advantage over the coated 50-mil track.

Mr. Athey: Apparently the spectrum problem of low-frequency pre-emphasis does not seem to worry anybody very much. I assume that something is supposed to give in the system at high levels. You may notice that I pointed out that in a sense we take advantage of it in order to reduce some of the requirements on our amplifiers. It seems to me that the real reason for low-frequency pre-emphasis, which I don't believe has been made too clearly here, is that we have a perfectly fantastic hum problem. I have made some very crude calculations here and I believe that for a 50-db signal-to-noise ratio, the hum signal must be less than −144 dbm at the input of the preamplifier. This is a fairly severe hum problem and I therefore hope that we do not give up more than a db or so of the present low-frequency pre-emphasis.

Mr. Wirth: I would like to comment on some of the points that have been made. For one thing, I think that the concept of using high-frequency pre-emphasis to compensate for inefficiencies in head design or difficulties thereof is one of the evils of the magnetic recording industry.

The amount of pre-emphasis that Ampex used for the Magna Theatre Corp. was not tied down to any particular set of specifications, since it was a development system which we hoped would be superior to anything that existed before. It therefore gave us the opportunity for experimentation to our heart's content with the variety of possible paths available. We made a great number of narrow-track listening tests with different pre-emphasis characteristics in order that our conclusions would be based on CinemaScope conditions. I think that's the whole key to this discussion; we are now dealing with very narrow track magnetic stripes. With the replaying of CinemaScope films, no doubt, we will be able to get some quantitative information as to deterioration of signal-to-noise ratio due to the rubbing-off of the oxide, and other effects.

We're not saying that this proposed pre-emphasis characteristic is, by any means, the last word, but we're certainly interested in finding out what other people think about it.

Mr. Athey: Was this equalization for a half-mil playback gap? Since our present system is designed for the half-mil gap we wouldn't like to go to a larger gap.

Mr. Wirth: A ¼-mil gap is used.

Ralph H. Heacock (RCA Victor Div., Camden, N.J.): There are several minor things that have come up in the field about which there may be some confusion. Someone asked about the adaptability of the various manufacturers of button-on units to various projectors. I think broadly and from an engineering viewpoint, certainly all manufacturers plan to have their units adaptable to any type of projector that may be available in the field, but from a practical viewpoint at the present time we are so very busy producing equipment, that it may be that we haven't gotten around to making the necessary adaptor plates for some particular projector and, because of that, a report gets around that a certain unit will not work with a certain type of projector. Well, that may be only because that particular adaptor plate is not available to meet the necessary close opening date of a particular theater, so that probably, in the course of the next few weeks, it will be correct to say that any one of the units, at least to the best of my knowledge, will work with practically any one of the projectors in the field.

There was one other question that was asked by someone about the standardization of sound take-off with relation to picture take-off. It's my understanding that the sound lags or follows the picture by 28 frames, so that there is actually a lag of 28 frames with all of the button-on types of sound heads.

One other question that came up: someone asked about the effect of the narrower sprocket teeth when used with the conventional sprocket hole in the film. In general, the studio guides of the projector are the determining factor for lateral weave, so that even though the tooth is narrower than has been the practice in past years, the studio guides will still be the determining factor in lateral weave. It would, therefore, be my guess that it should not be any worse with a narrower tooth than it has been in the past with the standard tooth. There has been a lot of discussion about the new CinemaScope sprockets. That, I think, is probably a matter that comes under the Film Projection Practice Committee. Our meeting is at 2:00 o'clock on Thursday afternoon and we would very heartily welcome anyone who wants to come in and express any comments on the new types of sprockets, the root diameters and any other things that have been revealed in work of, say, the last six months, so that we can have the value of your experience in our Committee meeting.

Mr. Hilliard: What do you mean by studio guide?

Mr. Heacock: It's a long guide which is located in the film trap on each side of the film. In general, these are adjustable, so that if we say that a 35-mm film would be the distance between my two hands, this guide against which the edge of the film moves, is stationary. This one is adjustable, so that you adjust this guide to give you the steadiest picture possible, taking into account the variation due to shrinkage in the width of film. It is that adjustment that is generally the determining factor in lateral weave of the film in the film trap.

Mr. Zambuto: I asked the question about the different sprocket holes and lateral weave. There happen to be a certain number of moments in which the lateral guides fail to be the determining factors. Most of the time, when a splice goes by, you find the lateral guide fails to be the determining factor. But I was thinking of something else. It's everybody's experience that when the film is a little warped, or the perforation a little damaged, you find that the film is not correctly fed to the lateral guide. In such irregular feeding the tooth may easily become the limiting factor, by determining the strain on the lateral guide.

Mr. Heacock: I believe that at the instant that a film splice or some other irregularity occurs in the film trap, that the conditions may be quite unusual. But, of course that's an extremely small percentage of elapsed time and I still feel that, whether you have the CinemaScope width of tooth or whether you have what has been our old standard width of tooth, you will still find that studio guides are the determining factor and it would be my guess that the situation might not be seriously different with the CinemaScope sprocket just for that instant, as compared to that when the standard sprocket is used. However, any other comments will be welcome.

Magnetic Head Wear—Panel Discussion

JOHN G. FRAYNE, Moderator

Editorial Note: "Ferrite-Core Heads for Magnetic Recording" by R. J. Youngquist and W. W. Wetzel, presented at the same Convention session as this discussion on magnetic head wear, has not been released for publication. The tentative conclusions put forth at the Convention have been withdrawn because continuing tests on ferrite-core heads have not borne out the earlier hopes.

At the end of the discussion, Dr. Frayne called for all concerned to add data when they received the draft of the discussion transcript.

Edward S. Seeley (Altec Service Corp.): First, who has seen operational or performance evidence of head wear; and second, what has been the nature of the performance change as a result of wear?

This discussion was held on October 9, 1953, at the Society's Convention at New York, with John G. Frayne as Moderator.

John G. Frayne (Westrex Corp.): I have seen physical evidence of head wear.

Mr. Seeley: How about performance evidence?

Dr. Frayne: Yes, we have noticed change in performance, particularly with respect to high-frequency response and erratic contact. I have no exact figures, but that we have head wear cannot be questioned. It is our estimate that with Westrex magnetic heads used in studio recording and reproducing equipment we obtained somewhere between 3,000,000 and 5,000,000 ft of wear without any serious changes in characteristics.

R. H. Heacock (RCA Victor Div., Camden N.J.): We have one actual operating theater experience that was of interest to us. This was in the first installations of double-film systems that were made with nterstate down in Texas, when they led off mmediately following the opening of *The louse of Wax* here in New York. After a onsiderable period of time had elapsed, ve had the same RCA service engineer, vho had made his measurements on orignal installation, return to the theater with he same equipment and make another set f tests jointly with Interstate engineers. After what we estimate to be approxinately 6,000,000 ft of film travel, we found hat lowering of the output level was, from practical viewpoint, negligible; and the vear was not visibly apparent. That's the nly specific case that we know of where ve feel the results were accurate enough by irtue of having the same personnel, the ame test equipment, the same units and n identical check made. Frankly, the esults have surprised us. We didn't expect hat we would be able to run 6,000,000 ft of film without having more difficulty than ve have experienced in that particular heater.

Dr. Frayne: How much of a factor might he tension on the films be, in this case?

Wallace V. Wolfe (RCA Victor Div., Hollywood, Calif.): It is significant in that connecion that this is a soft-loop type of machine. The pressure on the head would probably be somewhat lower than would be the case n the tight-loop machine. But exactly vhat it measures I don't know.

Dr. Frayne: Is that a full-coated film or he CinemaScope film we're talking about?

Mr. Wolfe: That's a full-coated film.

Mr. Heacock: This is a typical double-film ystem with separate sound coating. One other comment: we made a number of nagnetic reproducer heads to have them available for field maintenance of our button-on soundheads. I don't believe we've had to use any of these reserves.

Mr. Wolfe: As to wear of heads in studio equipment, we find these things happening. The inductance of the head does go down as it wears; this is an obvious fact, and significant for these reasons. The frequency characteristic is a function of the bias current; and the bias current, in turn, s a function of the inductance of the head. Consequently, as the head wears, the frequency characteristic changes. The frequency characteristic can be brought back by appropriately changing the bias current.

[See: Kurt Singer and Michael Rettinger, "Correction of frequency response variations caused by magnetic head wear," *Jour. SMPTE, 61:* 1–7, July 1953.]

Skipwith W. Athey (General Precision Laboratory): The basic problem that Mr. Heacock described, and which, I believe, is the major concern as far as CinemaScope and double-film systems are concerned, is how much wear the theater gets out of the film on playback rather than the recording situation. I don't think many of us can get too concerned about the cost of the manufacture and operation of the recording equipment, because so few of us can see those dollars slipping away; but if the theater owner has to replace heads at a great rate, then that is of great concern. I have not had enough experience with wear on CinemaScope film to say what the effects of wear are. Am I correct that we would normally expect an increase in output with wear because of the reduction of the inductance of the head? This is for playback only. And am I not correct that unless resonance in the amplifier is changed in a major way we should expect an increase rather than a decrease in high-frequency response?

W. W. Wetzel (Minnesota Mining and Mfg. Co.): It's my opinion that the only two things which affect frequency response are bias effect on record and the gap effect on playback. Now all heads are constructed with a certain 20 to 25 mils of magnetic material which can wear away before the gap starts to widen and I don't believe we expect a change in frequency response resulting from that wear until it begins to get down into the V-shaped lower portion of the head. Then the gap widens. You do lose frequency response quite rapidly.

Mr. Athey: May we expect some low-frequency effects as wear changes the effective gap?

Dr. Wetzel: I think that they wouldn't be adverse, since you're increasing the length of gap. What you'd be afraid of doing is getting those funny little humps.

Mr. Athey: Or moving them too violently.

Dr. Wetzel: That's right.

Mr. Athey: Because they're certain to be there anyway.

Dr. Wetzel: That's right.

Mr. Athey: Some experience can be reported for the General Precision Laboratory

CinemaScope "penthouse" reproducer. At the Roxy the film has run for three weeks. For the first two days of this run, only two projectors were used; then the third projector was put in service. The Roxy is running six shows weekdays and four on Sunday — 40 shows a week. The picture is about 15,000 ft long. So about 800,000 ft of film have gone through the installation.

I have seen samples of film which had run almost three weeks, and the film isn't a very attractive thing, mechanically speaking. The burnished surface of the track generally looks as if you couldn't get anything in the way of decent sound out of it, but it continues to deliver decent sound and there appears to be no appreciable wear or damage to the film itself after this period of time.

Even in the laboratory you can't catch up on the theater very much in a life test because there are only 24 hours in a day. Most of us haven't had a head that we could put off to one side and run for a life test. I think we're just about getting to the point where we might think about that. Our only life test is usage in the field.

E. K. Carver (Eastman Kodak Co.): I've heard more worry about the narrow track wearing a groove in the sound head that overlaps it than about the wide tracks wearing the narrower heads down smooth. Is there anything to that?

Dr. Frayne: Yes, there probably is. Of course, in the CinemaScope system, three tracks are wider than the associated heads and this problem does not arise. It does arise on the fourth, or effects, track where the track is narrower than the head and the problem of the narrow track wearing a groove in this head is a reality. Is that correct, Dr. Wetzel?

Dr. Wetzel: It is hardly necessary for me to agree with it. RCA engineers presented at the SMPTE meeting in Washington a paper which was later published in the *Journal*, which shows the effect of half-track wear on mu-metal heads. It's very definitely present. [G. A. Del Valle and L. W. Ferber, "Notes on wear of magnetic heads," *Jour. SMPTE, 60:* 501–506, Apr. 1953.]

Malcolm G. Townsley (Bell & Howell): Most of the conversation about stepwise wear due to narrow tracks on wide heads has occurred in the 16mm field where there is quite a lot of 50-mil track used on 100-mil heads, with a good deal of worry about the wear effects. At the meeting in Washington the RCA data, to which Dr. Wetzel referred, were presented; there were some verbal data given by Bell & Howell and I think a comment by one of the Reeves Soundcraft engineers has later been confirmed by our own results. He said, in effect, that the dirt on the film contributes at least as much and perhaps more to wear of magnetic heads than the oxide coating itself. Usually you can see a slight difference in pattern on a head that's been run a great deal with 50-mil track, but after you develop this slight difference in pattern, the whole head wears down quite uniformly. We have just finished a set of tests in which we ran a 100-mil head with 50-mil track, replacing the track often enough to overcome the burnishing effect, because, as a film is passed continuously over a head, it burnishes itself and doesn't wear the head so fast anymore, and the performance of the head when tested with 100-mil track was substantially unimpaired at the end of 1100 hours. Now 1100 hours corresponds to something over 2,000,000 ft of 16mm film. (Note: this head has now (Nov. 4) run 1400 hr.)

E. W. D'Arcy (De Vry Corp.): I think the point that Mr. Townsley brought out is very pertinent about wear on the head. We were not concerned with regard to wear on the head as much as damage to the area adjacent to the magnetic track, and there certainly is enough wear to cause damage to it.

Dr. Frayne: I would like to add that in our organization on the West Coast we have started a systematic study of head wear with CinemaScope tracks, and information from this study should be available within a few weeks. I shall be very happy to add our findings to this discussion when it appears in the *Journal*.

Additional comment by Dr. Frayne,
Submitted November 5, 1953:

[A life test of a Brush BK-1544 CinemaScope Head in a Westrex R9 stereophonic reproducer has reached 900,000 ft of film. The film tension in the R9 averages 500 g in the upper and lower film paths, and with 15° wrap this equals 130 g pressure against the magnetic head. The head wear at the gap averaged $3\frac{1}{2}$ mils for the first 100,000 ft of film and has diminished in rate so that at the end of 900,000 ft it averaged 11 mils, but with a spread of about 5 mils between individual heads. The BK-1544 Head has a depth of about 20 mils at the gap, thus leaving an average thickness of 9 mils of mu-metal remaining at the gap. The 8000-cycle response dropped by an average of about 3 db from the initial value at the end of 300,000 ft, then rose to equal the starting point at 600,000 ft and then dropped about 1½ db below the starting value at the end of 900,000 ft.

[Film to head contact wear has not appeared to present a problem up to the present time. The inductance of the heads appears to diminish from the original value. It would seem that the head under test would continue to give reasonably satisfactory service for at least another million feet.]

Dr. Wetzel: I might add some rough calculations that are becoming apparent during this discussion. Let's take the 3,000,000 to 5,000,000 ft, which is approximately correct for the wide-head wear. Kurt Singer, Dr. Frayne, quite a number of people in the industry, appear to agree with that value. That means somewhere between 500 and 1000 hr. of actual machine operation. Let's assume that you have two projectors operating, two heads to wear. You're switching between these and you're operating over a period of 12 hr. That means 6 hr per day of actual head wear. Seven days a week means 42 hr per week and in 10 weeks it seems to me you might begin to expect a little trouble. Certainly I would expect it in 20 weeks.

Dr. Frayne: Along the same lines, I hope these optimistic predictions about head wear will not deter Minnesota Mining or other companies from their program of developing ferrite heads. It is well to remember that in standard photographic sound tracks the optical system was good for an indefinite operating life. Once in a while a lamp will burn out but a lamp replacement is relatively cheap. Compared to this, a 4-track magnetic head is going to cost — well, anywhere from $75 to $125. This presents a very serious economic problem to the theater owner and I am sure we all hope that somebody will come up with a successful ferrite head that will have an extremely long life.

Mr. Seeley: I wholeheartedly agree; but, in the meantime, we have to continue using the heads we have and are currently receiving in the field. We in the service companies are very much concerned over this matter. Most of the remarks have related to visible effects of wear. Of more interest are performance effects. I have assumed that wear would possibly produce a slow increase in mid-frequency level and in addition some slight decrease in reproduced high-frequency level due to increase in resonance frequency resulting from reduction of inductance. There will also probably be effects resulting from changes in the relation of the film to the gap.

John K. Hilliard (*Altec Lansing Corp.*): Most of the magnetic heads are designed for a 30-ohm circuit. It would appear that since the head inductance is decreasing, there could be a tendency to have a resonance at a high frequency because of the leakage inductance in the input transformer. This is caused by the fact that as you lower the impedance of the generator or driving transformer, the effect of the leakage inductance becomes more of a factor and would vary with the type of input transformer used. In some cases this will be of only theoretical importance, but with input transformers having a very high leakage value, it may cause a marked peak in the high-frequency end.

Col. Richard H. Ranger (*Rangertone, Inc.*): I can't give you any information on magnetic film, but I think the reaction would be quite similar on ¼-in. tape. We get anywhere from 15,000 to 20,000 hr on a head, but the thing that disturbs you when it does wear is dropouts. In other words, you actually lose contact, and once you do that, there is nothing but to get a new head or refinish it. The frequency changes are, generally speaking, immaterial.

Portable 16mm Arc Projector Adapted for 3-D Projection

By J. J. HOEHN, A. J. CARDILE and RALPH A. WOODS

A new portable arc projector for 16mm film, consisting of five luggage-type units, and its modification for 3-D projection, is described.

The RCA Porto-Arc 16mm Projector is designed to provide sufficient light and audio-power output to handle larger screen sizes and audiences than can be accommodated with projectors using conventional incandescent-lamp light sources. The design was made possible by the development of a dual operating-range 16mm arc lamp and associated rectifiers small and light enough to justify the use of the term "portable." This lamp has been integrated into an overall projector design which allows the equipment to be separated into readily portable units. For example, the arc lamp is easily disconnected from the projector mechanism, and both units merely lift off the pedestal-amplifier assembly to make sections which can be conveniently handled and transported.

Presented on October 8, 1953, at the Society's Convention at New York by J. J. Hoehn and A. J. Cardile (who read the paper), Radio Corporation of America, RCA Victor Div., Engineering Products Dept., Camden 2, N.J., and Ralph A. Woods, Hopkins & Woods, Martinsville, Ind.
(This paper was first received October 7, 1953, and in revised form Dec. 24, 1953.)

Mechanical Design

Figure 1 shows the Porto-Arc Projector disassembled for transportation. First on the left is the pedestal-amplifier assembly, which is about the size of a large suitcase of conventional proportions. As is usually the case where a piece of apparatus closely resembles a familiar article of everyday life, the pedestal-amplifier has quickly come to be called, "the suitcase." Out of deference to the Society's Nomenclature Committee we shall refrain from use of the term hereafter in this paper.

The second item from the left in Fig. 1 is the portable loudspeaker regularly used with RCA Model 400 16mm Projectors. The third item is the dual-range arc lamp, and next is its associated rectifier for converting a-c line power to the low-voltage direct current required for proper operation of the arc lamp. The fifth and last item is the projector mechanism; reel arms and small accessory items are mounted within its housing. The heav-

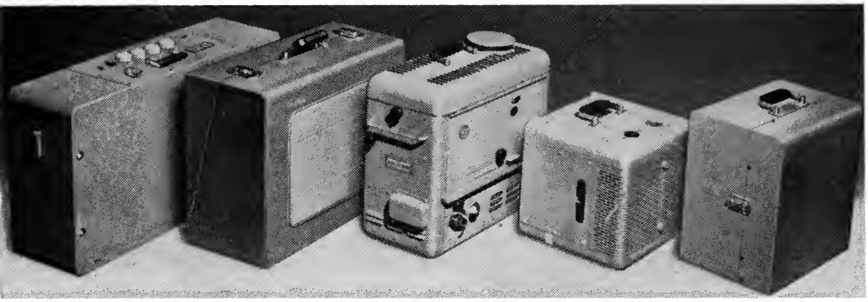


Fig. 1. The RCA Porto-Arc 16mm Projector is complete in five cases.

iest items are the pedestal-amplifier and the rectifier, which weigh about 60 lb each due to the inevitable weight associated with transformers of adequate performance characteristics.

Figure 2 shows the Porto-Arc Projector set up and operating. The projector mechanism and the arc lamp lock firmly together in correct optical alignment by means of guide pins, locating holes, and an aircraft-type cowl fastener. This feature was considered to be essential in a machine intended not only for portable service and professional projection, but also for operation by relatively inexperienced personnel. The assembled mechanism and lamp rest on the upper surface of the pedestal-amplifier case as shown, supported by the rear arc-lamp feet and by the movable front pins of the tilting device incorporated in the case. The pedestal legs are splayed a considerable degree laterally and longitudinally to provide excellent mechanical stability for the complete projector.

The pedestal-amplifier assembly has separate compartments to contain its demountable legs and the interconnecting cables, and it also incorporates the 5° tilting mechanism in the front operated by a fold-in crank. Adjustable legs accommodate the projector optical axis to existing projection room portholes and "up" or "down" projection angles. All interconnecting cables are provided with suitable plug connectors of a variety of types to prevent incorrect connections. In other words, if the plug on a cable end fits a given socket, it is the right plug for that socket.

Amplifier

Figure 3 is an interior view of the pedestal-amplifier case with the control panel removed to show the amplifier chassis. The amplifier incorporates

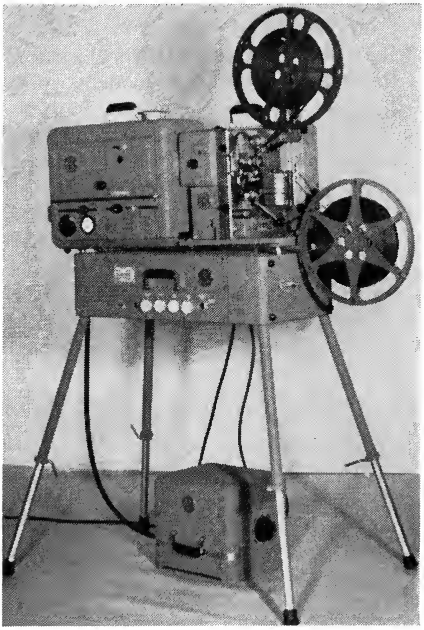


Fig. 2. RCA Porto-Arc set up in operating position.

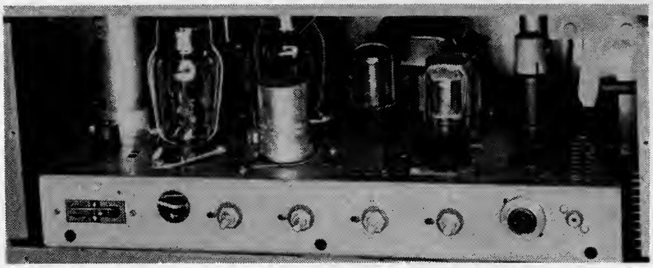


Fig. 3. Pedestal-amplifier case with control panel removed to show amplifier chassis.

the same type of high-frequency exciter lamp oscillator and tilt-type tone control used in RCA Model 400 16mm projectors, but the power output has been increased to 25 w for the larger audiences which can be served with 16mm arc projectors. There are individual mixer-type volume controls for the film sound channel, record player and microphone. The main power circuit to the projector enters via the magnetic circuit breaker at the left end of the amplifier chassis. Its time constant allows for the arc-striking current surge, but it opens before a thermal line fuse of equivalent rating will blow. Accidental overloads therefore operate a protective device at the projector location, and not at some possibly distant or inaccessible point. This feature, along with the automatic optical alignment of lamp and projector mechanism, was felt to be of importance in a machine capable of being operated, on occasion, by nonprofessional personnel.

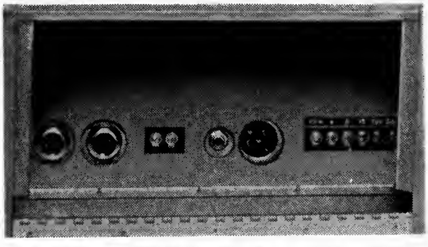


Fig. 4. Rear view of pedestal-amplifier showing connections.

Figure 4 is a back view of the pedestal-amplifier case with the cable access door open. The two shielded-cable jacks at the left are for the projector mechanism phototube and exciter lamp circuits, respectively. The phototube circuit is triple-shielded to prevent interference pickup from the relatively strong fields existing around the arc circuits. The phone jack and pair of terminals to the left of it are both the loudspeaker output circuit from the amplifier so that either temporary or permanent connections can be made. The multiterminal strip at the right allows the output impedance to be changed to match the characteristics of the loudspeaker equipment being used. The output circuit from an RCA MI-35102 Magnetic Reproduce Kit installed in the projector mechanism may be connected to either the microphone input circuit, if both photographic and magnetic sound tracks are to be run, or to the phototube circuit jack in the rear if magnetic tracks only are to be reproduced.

Projector Mechanism

Figure 5 is a close-up of the projector mechanism. Except for certain modifications and additions required by the arc application, it is the same as has been used for some years in RCA Model 400 16mm projectors. Visible in the figure just above the picture gate assembly is the head of the cowl-lock fastener which locks the mechanism to the lamp. Below and to the left is the theatrical-type framer control knob which shifts the moving film with respect to the aperture, and directly below it is the speed-shift control which changes the film speed from 24 frames/sec to 16 frames/sec. The motor switch is at the bottom of the control panel.

Since it is impractical to interlock the projector motor and lamp power circuits as is done in incandescent lamp projectors, it was considered essential that the RCA Porto-Arc Projector incorporate an automatic film-speed operated fire shutter to protect the film in the event of accidental film stoppage. By careful mechanical design, it proved possible to combine this function with that of a hand-operated "dowser" for keeping the light off the screen until the start of picture action. A centrifugal clutch was added to the regular picture shutter hub, and this clutch, via suitable linkage details, lifts an auxiliary shutter or "dowser" blade whenever the mechanism film speed exceeds 14 frames/sec, and provided the manual control lever for it is unlatched. This lever is visible in Fig. 5 just to the left of the framer control and may be identified by its horizontal knob. A simple notch in the lower edge of the lever provides the latched-shut feature. Slightly lifting the knob and pulling outward on it opens the dowser/fire shutter, but it

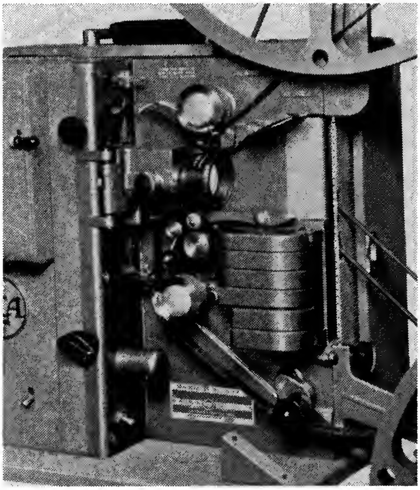


Fig. 5. The 16mm. Projector Mechanism.

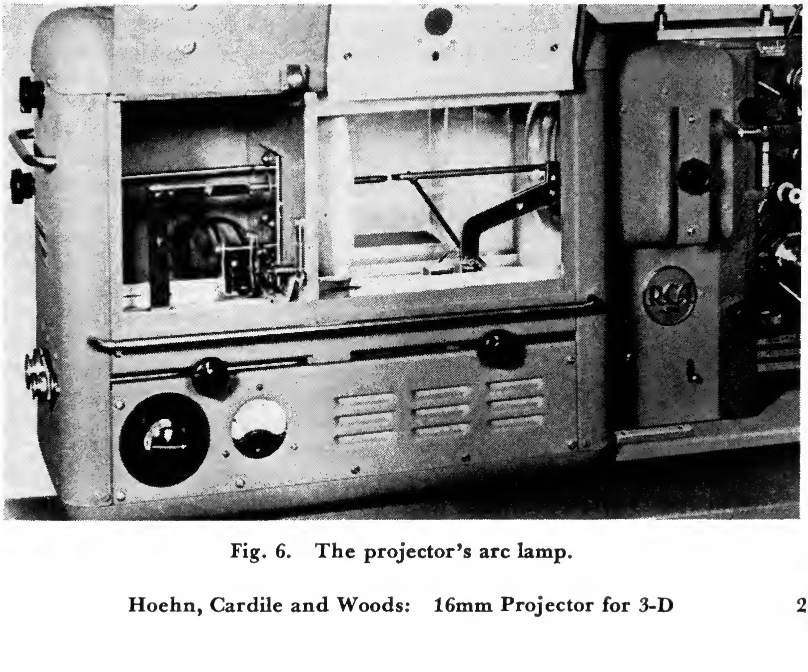


Fig. 6. The projector's arc lamp.

will not stay open unless the mechanism film speed exceeds 14 frames/sec as noted. Below this speed gravity forces in the linkage pull the blade closed, and it stays closed until the control lever is again manually lifted to unlatch it.

The housing for the 3450-rpm centrifugal blower normally associated with the projector mechanism's drive motor has been modified to provide strong cooling air blasts for the condenser lens, heat filter and picture aperture. Since the blower speed is the same at either 16- or 24-frame film speeds the cooling action is likewise the same, but of course the longer dwell time of the film in the aperture at the slower speed does call for the use of the heat filter for nearly all films being projected at this rate.

Arc Lamp

Figure 6 shows the arc lamp with the operating-side door open and with the cover for the feed-ratio pulleys removed. The relatively small, compact housing design is made possible by the selection of a combination reflector-condenser optical system. In the Porto-Arc Projector the length of the lamp has been further reduced by mounting the condenser lens in the projector-mechanism housing. Many design details result from manufacturing experience gained in the production of Hopkins & Woods "Sup-R-Arc" lamps for 35mm film projection, which were marketed also under other brand names by various 35mm equipment manufacturers.

The lamp is designed to operate with either the standard 30-amp, 28-v Pearlex carbon trim, or with a new 10-amp, 50-v trim. The 30-amp trim, without heat filter in place and with the optical system adjusted for 70% side-to-center distribution, delivers 1600 lm, using the two-blade 80° shutter normally supplied, and an $f/1.6$ lens. The 10-amp trim under the same conditions delivers 850 lm, which is in the order of twice that available from ordinary incandescent-lamp 16mm projectors. One 30-amp trim lasts 56 min, which accommodates a 2000-ft reel at 16mm sound speed. By contrast, the 10-amp trim burns 2 hr 15 min, which accommodates 4000-ft reels, though special feed and take-up facilities, which are being designed, are required. It is felt that this relatively long operating time without need for intermissions will eventually find considerable application, particularly in the foreign field where single-machine theater operation is common. The greater light output, as compared to presently used incandescent-lamp projectors, should materially improve the picture quality in such situations.

In Fig. 6 the outer edge of the elliptical reflector or mirror shows approximately in line with the left edge of the heat shield on the opened door. It is $7^1/_2$ in. in diameter and is mounted on a vertical baffle within the arc lamp by a three-point, spring-seated suspension. The center of the mirror is over 3 in. behind the arc to reduce fogging tendencies from arc gases. Two control knobs extending to the back of the arc lamp from the reflector's spring-mounted support frame provide tilt and training adjustments for uniform illumination of the projector-mechanism aperture. The working distance of the mirror alone is 25 in., but for the combination of mirror and condenser the working distance is less than 17 in. The optical speed of the combination is approximately $f/1.6$, which matches well with the speed of the fastest projection lenses customarily used. The condenser lens is situated about 13 in. from the mirror and is made of heat-resistant glass. It not only performs the optical function noted, but also effectively serves as a barrier to prevent cooling air currents from disturbing the arc. The condenser lens is mounted in a pull-out carriage visible in Fig. 6 just above the RCA monogram. It can thus very easily be inspected and cleaned when necessary.

Other items of interest visible in Fig. 6 are the positive-carbon holder and carbon-tip guide, which are designed to obstruct the minimum possible light from the reflector. To the rear of the mirror supporting baffle is the negative-carbon holder, and just below it may be seen the mercury interlock switch actuated by the lamp door. For maximum operator safety it disconnects the arc rectifier from the power-supply circuit as the door is opened.

When the lamp is in operation the two carbon holders are moved slowly toward each other within the lamp base by their supporting carriages, which ride on two longitudinal feed screws. The carriages may be manually positioned along the screws for arc trimming and striking by means of the control knobs operating in the slots just below the door opening. Stops for the carriages cause the feeding action to cease when carbons burn down to stubs 2 in. long, thus preventing accidental damage to holders and tip guides. The ends of the feed screws protrude through the rear of the lamp housing as shown and support double-groove spring-belt pulleys. Moving the belt from one set of grooves to the other changes the negative/positive feed ratios to suit the relative burning rates of the two different carbon trims for which the lamp is designed.

The feed screws are driven by a specially wound d-c series motor connected to the arc circuit via an arc-current operated relay so that feeding action does not begin until the arc is struck. This effectively prevents accidental freezing of the carbons if power is inadvertently left on without striking the arc. The series motor circuit includes the average feed-rate control rheostat shown just to the left of the arc-current ammeter. In addition to the normal series motor-type field windings, the feed motor carries an additional field winding through which the arc current passes. The combined forces of the resultant fields provide a very effective stabilization action for the burning arc; for example, if the arc current tends to rise, say because the line voltage has gone up a few volts, the feed motor slows down so the arc gap lengthens slightly to bring the current back to the former value. The reverse action occurs if the current tends to fall. Small changes in burning rates due to nonuniform carbon composition are also compensated to a considerable extent by this stabilization action.

Figure 7 is another close-up of the arc lamp with the condenser carriage pulled out to show the heat filter. Also visible in this view is the rigid-tip guide for the negative carbon. The filter-glass strips are carried in an auxiliary holder which is easily slipped in or out of mating guides on the condenser carriage as shown. Experience to date has shown that with the degree of aperture cooling provided it is possible to run nearly all color films safely at 30-amp operation without the heat filter because they are relatively transparent to the longer-wavelength radiant energy. The heat filter is usually required for black-and-white films unless they happen to be of rather low density. The filter is essential for all types of film when operating at the projector's 16 frames/sec film speed, but is not usually required for sound-speed 10-amp lamp operation.

At the top of the lamp in Fig. 7 the ventilation chimney shows. It incorporates a scoop-shaped inner section, extending downward just above the arc to the edge of the light beam, which serves as a collector for the carbon electrode combustion products produced by the burning arc. The chimney assembly pulls out for cleaning; the dust washes off easily in cold running water.

Two openings are visible in the heat shield on the inner surface of the opened lamp door in Fig. 7. The larger opening is provided with heat-resistant dark glass for observation of the burning arc. The smaller opening is the port through which light from the arc enters the mirror assembly of the lamp's "arcoscope" on the outer door surface. Referring to

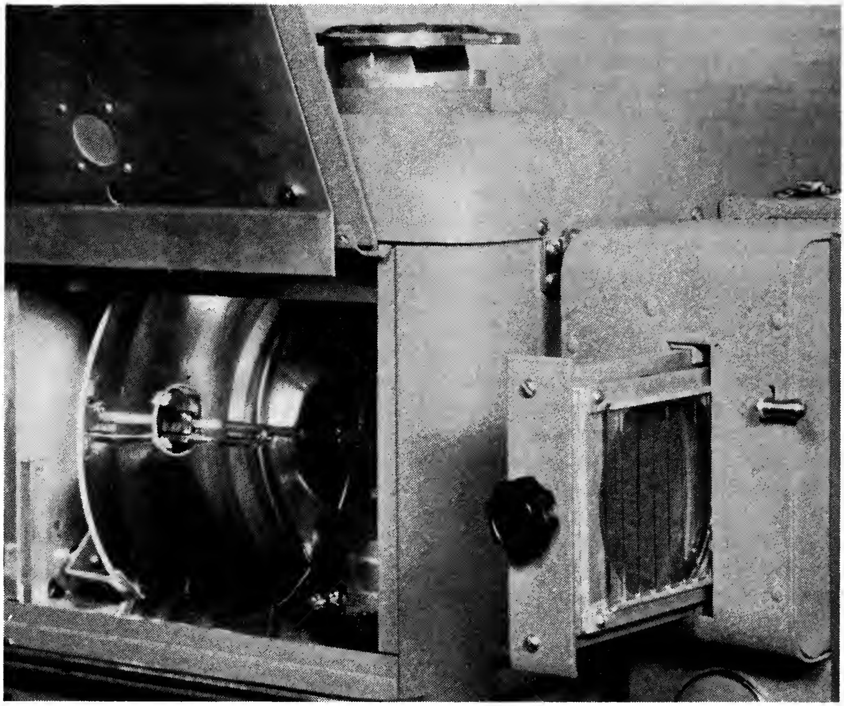


Fig. 7. The projector's heat filter design.

Fig. 2, which shows the door closed, the mirror assembly is seen just above the observation port, and it throws images of the brilliant carbon tips to the white screen directly below it. During initial testing of the lamp and projector mechanism the position of the burning arc with respect to the mirror is manually adjusted for maximum light output consistent with approximately 70% side-to-center light distribution on the screen. Lines are then scribed on the arcoscope screen marking the corresponding carbon-tip positions, and these lines become the references for subsequent lamp operation. As a rule, mirror characteristics are within tolerances which permit mirror replacement without scribing new reference lines, but alignment and focusing are simple operations easily carried out if necessary.

Figure 2 also shows the 30-amp rectifier in place under the pedestal-amplifier. The 10-amp rectifier is identical in exterior appearance. These rectifiers are used to convert alternating current from the power line to direct current required for proper operation of the arc. The 30-amp rectifier uses two standard 15-amp gas rectifier tubes; the 10-amp rectifier uses two 6-amp tubes. Both rectifiers are provided with primary tap switches to accommodate varying line voltage and load conditions.

Adaption for 3-D Projection

So far this paper has described single-machine setups of the RCA Porto-Arc 16mm Projector. Two-machine setups, with simultaneous, solenoid-operated change-over of picture and sound, are easily effected using conventional auxiliary equipment. Another type of two-

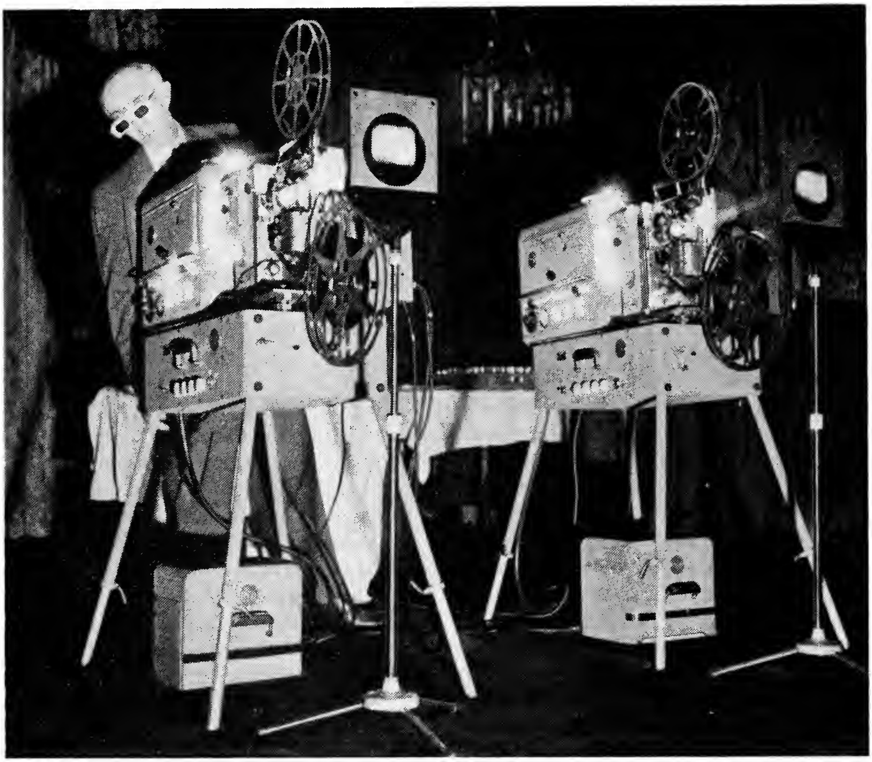


Fig. 8. RCA Porto-Arc 16mm Projector adapted for 3-D projection (photo courtesy Chicago Sun-Times), operated by George Karr of Local 110, Chicago Moving Picture Operators Union, IATSE, during demonstrations in July 1953.

machine setup involves the interconnection of two 16mm projectors to run exactly in step for the projection of "3-D" motion pictures by the double-film system. Mechanical interlock was considered and rejected as being impractical for equipment which must be readily transportable from one location to another. Complete selsyn (self-synchronous) drive systems of the type used to interlock studio recording and camera equipment would be satisfactory from the performance viewpoint, but tend to be heavy, complex and costly. Experience in the 35mm theater equipment field indicated that a modified type of selsyn interlock drive, in which the regular projector motors are retained to supply the needed driving power, with auxiliary selsyn coupled motors performing only the interlock function, gives entirely satisfactory results for projection. The auxiliary selsyn motors are reasonable in size and cost, and are relatively easy to couple into the regular projector-drive arrangements. This type of interlock drive system was therefore selected for the application of the RCA Porto-Arc Projector to 16mm 3-D projection, where its high light output is of extreme value in overriding the fairly large light losses inherent in the use of polarizing projection and viewing filters.

The 3-D version of the Porto-Arc Projector mechanism is provided with an extended base and enlarged rear cover to support and house the auxiliary selsyn drive motor. This motor is coupled to the main projector driveshaft and to the regular projector induction drive motor by means of sprockets and a toothed synthetic rubber "timing" belt. Motor circuits are carried from one projector of a pair to the other by means of cables and coded plugs capable of being inserted only into the proper mating receptacles. Facing the screen, the righthand projector of a pair normally has the most clearance around its operating position, so the master controls are installed on this machine. They consist of a master switch for simultaneously starting the two regular projector-drive motors, and a "lock-in" switch for the selsyn motor circuits to permit single-machine operation when desired.

Proper selection of timing-belt sprocket ratios provides for automatically correct phasing of the two film-transport movements after disconnection and reconnection of the interconnecting cables, once the initial phasing is carried out. This is accomplished by energizing the selsyn interlock circuits with the drive motors at rest, and then rotating the loosened sprockets on the selsyn motor shafts to bring the two movement claws as closely as possible to exactly the same points in their travel cycles, after which the sprockets are again tightened on the motor shafts. It is obviously necessary also that the shutter timing on the two projectors be identical, and that the framer settings be at least approximately so, though experience indicates that with the theatrical-type framing provided in RCA projectors, small vertical misalignments in the projected 3-D pictures can be compensated by framing without excessive deterioration in projected 3-D picture quality.

To facilitate threading the two prints of a 3-D film into the machines with the frames synchronized, the regular induction drive motors are provided with double shaft extensions and external handwheels so that the film transport movement can be brought manually to full claw protrusion for threading. With the selsyn "lock-in" switch closed, turning the handwheel on either machine operates both movements, which provides a ready check on the interlock action. As a matter of passing interest, it should be pointed out that the modified selsyn interlock drive system described does not provide absolutely fixed film speed since the main drive power is still supplied by the induction drive motors. The instantaneous speed stability is felt to be slightly better due to the larger mass of the coupled rotating components however, and of course all speed variations due to belt slippage are eliminated by the use of the timing-belt drives.

At the convention a special 3-D film produced by Raphael G. Wolff Studios was projected to show the potentially important applications of 3-D 16mm films in industrial, advertising and educational fields. At the moment it is anyone's guess as to whether or not 16mm 3-D entertainment films will ever be used in quantity. There can be no doubt, however, that 16mm 3-D films for selected applications, properly photographed and projected with adequate brilliancy, will enjoy well-deserved success for they provide the greatly enhanced realism and usefulness necessary for progress in any communication medium.

The Kinetics of Development by Vanadium Salts

By L. J. FORTMILLER and T. H. JAMES

This abridgment has been prepared for the Journal readers as a supplement to "Development of Motion-Picture Positive Film by Vanadous Ion," by A. A. Rasch and J. I. Crabtree, in the January 1954 Journal, pp. 1–10.

The rate of development of a motion-picture positive film by vanadous ion was measured at various temperatures, concentrations of vanadous and vanadic ion, and concentrations of acid and bromide ion. A special apparatus was employed which permitted continuous measurement of the developing silver during the course of the reaction. This apparatus was a modification of that described by Tuttle and Brown (*Jour. SMPTE, 54:* 149–160, Feb. 1950). The reaction chamber was made of Plexiglas, and the change of density in the developing film was measured continuously by means of infrared radiation passing through the reaction chamber and the film. This radiation was collected and measured by an IP22 photoelectric multiplier tube connected to an amplifier which fed a variable voltage Brown recorder. The readings on the recorder were converted to fixed-out density or metallic silver by means of calibration charts. The developer was stored and used in an atmosphere of nitrogen.

For a particular developer composition, the rate of image development follows a first-order equation to good approximation; i.e., the density, D, obtained in time, t, is given by the equation:

$$D = D_{\infty}(1 - e^{-kt}),$$

where k is the first-order constant. Development rates determined at various temperatures follow the Arrhenius equation; i.e., the logarithm of the rate is a linear function of the reciprocal of the absolute temperature. The temperature coefficient is 1.5 for an interval of 10 C, and the apparent activation energy is approximately 6.5 kcal/mole.

The dependence of development rate on the concentration of vanadous ion was determined for a solution which contained 0.38 M HBr, 0.05 M H_2SO_4, and varying amounts of vanadium. The total vanadium-ion concentrations were varied from 0.025 M to 0.10 M, and the vanadous-ion content from 21% to 99%. Over this range, the development rate is directly proportional to the concentration of vanadous ion and independent of the concentration of vanadic ion. The rate does not depend on the redox potential of the solution. The effect of acid was determined for a solution containing 0.083 M vanadium, of which 87% was in the form of vanadous ion, and sulfuric acid concentrations varying from 0.32 M to 3.3 M. The rate of image development shows little dependence on the acid concentration, but the rate of fog formation

Abridgment of Communication No. 1555 from the Kodak Research Laboratories by L. J. Fortmiller and T. H. James, Research Laboratories, Eastman Kodak Co., Rochester 4, N.Y. The full version appeared as a preprint of the Royal Photographic Society Centenary International Conference on the Science and Applications of Photography, London, September 1953.

increases with increasing acid concentration. The effect of bromide ion added as KBr was determined for the solution containing 0.32 *M* sulfuric acid. The rate of image development increases slightly with increasing bromide-ion concentration in the range 0 to 0.35 *M*. The rate of fog formation decreases with increasing concentrations of bromide over the range 0 to 0.06 *M*, but subsequently passes through a minimum and then increases. The increase may be attributed to the solvent action of the higher concentrations of bromide ion on the silver bromide.

Development by vanadium probably follows the simple chemical equation:

$$V^{++} + AgBr \rightarrow V^{+++} + Ag + Br^{-}.$$

The experimental results suggest that the rate-controlling step is the diffusion of the vanadous ion. The rate of development of liquid (uncoated) emulsion is very high compared with that of the coated emulsion, so that diffusion through the gelatin layer probably is the dominant factor in determining the rate of development of coated film. The first-power dependence of rate on vanadous-ion concentration and the low temperature coefficient, both, are in accord with this interpretation. The fact that the rate of image development increases slightly with increase in bromide-ion concentration is just the opposite from the expected result if the rate were controlled by a chemical reaction, but is in accord with expectation if the rate is controlled by diffusion. Increase in bromide-ion concentration increases the negative charge on the grain surface and should increase slightly the rate of diffusion of the positively charged vanadous ion in the immediate neighborhood of the grain. At vanadous-ion concentrations greater than 0.10 *M*, the rate of development no longer is simply proportional to concentration, and the diffusion process evidently becomes more complicated.

American Standards PH22.21, —.22, 1953, 8mm Motion-Picture Film, Usage in Camera and Projector

Published on the following pages are revisions of two American Standards: Z22.21-1946, Emulsion Position in Camera for 8mm Silent Motion-Picture Film; and Z22.22-1947, Emulsion Position in Projector for Direct Front Projection of 8mm Silent Motion-Picture Film. The revisions are purely editorial in nature, consisting of a change in title and use of the word "rate" in place of "speed" in paragraph 2.—*H.K.*

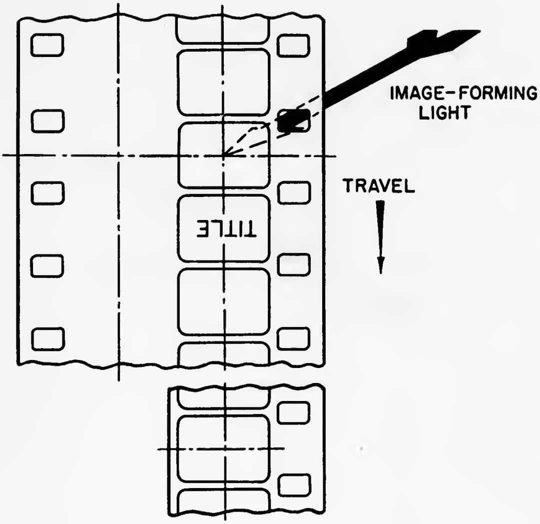
American Standard

8mm Motion-Picture Film Usage in Camera

ASA
Reg. U.S. Pat. Office

PH22.21-1953

Revision of Z22.21-1946
*UDC 778.53



Film as seen from inside the camera, looking toward the camera lens.

1. Position of the Emulsion

1.1 Except for special processes, the emulsion shall be toward the camera lens.

2. Rate of Exposure

2.1 The normal rate of exposure shall be 16 frames per second.

Note: This standard differs from the 1941 and 1946 editions solely in editorial modifications.

Approved December 17, 1953, by the American Standards Association, Incorporated
Sponsor: Society of Motion Picture and Television Engineers

*Universal Decimal Classification

Printed in U.S.A.
ASA1½M351

Price, 25 Cents

American Standard

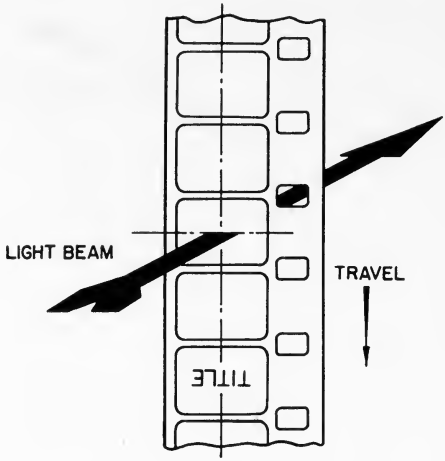
8mm Motion-Picture Film Usage in Projector

ASA
Reg. U.S. Pat. Office

PH22.22-1953

Revision of Z22.22-1947

*UDC 778.55



Film as seen from the light source in the projector.

1. Position of the Emulsion

1.1 Except for special processes, the emulsion shall be toward the projection lens.

2. Rate of Projection

2.1 The normal rate of projection shall be 16 frames per second.

Note: This standard differs from the 1941 and 1946 editions solely in editorial modifications.

Approved December 17, 1953, by the American Standards Association, Incorporated
Sponsor: Society of Motion Picture and Television Engineers

*Universal Decimal Classification

Printed in U.S.A.
ASA½M354

Price, 25 Cents

75th Convention — 60-Year Old Flickers — Television

Members at the Spring Convention will have a chance to see some of the earliest motion pictures. The Library of Congress and the Academy of Motion Picture Arts and Sciences have been instrumental in the successful conversion to 16mm film of some of the interesting old paper contact prints that were deposited with the Copyright Office of the Library of Congress between 1894 and 1912. During that period there was no provision in the copyright law referring specifically to motion pictures, but there was a provision for the registration of copyright claims for photographs. Producers therefore protected their works by registering paper prints of their 35mm films. The films themselves have in most cases disintegrated or been lost in other ways, so that these paper prints constitute a unique record which now for the first time becomes available for practical demonstration.

Through the courtesy of the Academy a number of these reprints will be shown during the Convention sessions. Originally, the motion picture was considered to be a gimmick for clearing vaudeville houses. It was believed that people could not stand more than 10 minutes of the "flickers." Let's hope that this interesting application of the art may possibly serve to keep sessions running to schedule.

A representative group of these early titles includes *Gatling Gun Crew in Action*, *The Corset Model*, *The Way to Sell Corsets*, *The Ex-Convict*, *The Girl at the Window*, *An Englishman's Trip to Paris from London*, *Great Baltimore Fire*, *Latina*, *Contortionist*, *International Contest for the Heavyweight Championship*, *Squires versus Burns*, *Automobile Race for the Vanderbilt Cup*, and *The Inn Where No Man Rests*.

Some or all of these will be shown as opportunity permits. In the main, however, early flickers or later motion-picture short subjects will be chosen in relation to the subjects of sessions. Other early films, especially some in color, are also being made available through the helpful offices of Margaret Herrick, Secretary of the Academy of Motion Picture Arts and Sciences.

The entire motion-picture short subjects program for the 75th Convention is under Motion-Picture Chairman Jack McCullough, Motion Picture Association of America, 28 W. 44 St., New York 18. Convention authors and members are asked to send Jack advice about what they would like to see on the program.

Program Chairman Aiken reports that the sessions and subjects as announced in the December *Journal* have been revised slightly in that: (1) there will be High-Speed Photography Sessions on Thursday afternoon and Friday morning; and (2) Television Sessions on Friday morning and afternoon will include, in addition to the papers announced earlier, the following:

"CBS Color Television Staging and Lighting Practices," by Richard S. O'Brien, CBS, New York.

"Color Kinescope Recording Methods," by E. D. Goodale, NBC, New York.

"Continuous Film Scanner," by Otto Wittle, Camera Works, Eastman Kodak Co., Rochester, N.Y.

If you do not have reservations at Washington, refer to p. 183 of the February *Journal* for information about the Hotel Statler for May 3–7.

The Convention Notice containing the Advance Program with brief abstracts for the papers has been mailed to the membership. Additional copies are available from Society headquarters.

SMPTE Officers and Committees: The roster of Society Officers and the Committee Chairmen and Members were published in the April 1953 *Journal*. A new roster is being prepared for the April 1954 *Journal*.

Engineering Activities

New Engineering Vice-President, Axel G. Jensen, faced as his first official task the appointment of all engineering committee personnel who, according to the Society's Bylaws, serve for a two-year term. Chairmen may be reappointed for a second term and members may be reappointed for any number of terms. Under these rules eight former chairmen, seven new chairmen, and some three hundred committee members, of whom 5 to 10% are new to committee work, were appointed. A complete roster of engineering committees will be published as usual in the April *Journal*.

Dissolution of the Test-Film Quality Committee was approved at the January 1954 meeting of the Board of Governors. This committee was established about three years ago to help improve quality control of test films sold by the Society, but the need for it has since disappeared. Its dissolution recognizes that Fred Whitney, Staff Test-Film Engineer, is ably executing the quality-control function.

The Board similarly approved **Dissolution of the Theater Engineering Committee.** Through the years specific aspects of its original functions were siphoned off into other more specialized committees such as Screen Brightness, Film-Projection Practice, and Sound, giving it finally an official field of interest limited to such items as theater carpets and air conditioning, valuable in themselves but covered adequately by those industries. The technical revolution in the motion-picture industry temporarily revived the committee, providing urgent need for a theater-screen survey that was launched in May 1953 and finished late in the year. With the conclusion of the survey (see the Report in the January 1954 *Journal*) it appeared reasonable and desirable to dissolve the committee.

The two committees on **Films for Television and Television Film Equipment** have now been combined into one, chaired by Gentry Veal and named simply **Television Committee.** Its new scope, given below, is a combination of the two previous ones.

The close interrelationship between the work of the two committees together with the rather large overlapping of personnel provided a natural basis for this union. It is anticipated that this step will make for greater efficiency in committee activity and will speed the development of specifications for a color-television test film, the major project before the committee.

Scope: To make recommendations and prepare specifications on all phases of film equipment used in television broadcasting. Further, to make recommendations and prepare specifications on all phases of the production, processing and use of film made for testing of and transmission over a television system.

A comprehensive, definitive **Motion-Picture Nomenclature** has been a long sought but little realized goal. Some two years ago an Interim Committee on Nomenclature was formed (reported on p. 549 of the June 1952 *Journal*) in an attempt to further this work. A spirited effort was made but the immensity of the job was too much for any one committee and it too fell by the wayside. But the goal is still bright and a new effort is now being made to reach it in a series of short, discrete steps via a coordinated assignment of work to each of the engineering committees. In his letter to the chairman of each committee Mr. Jensen stated, "It has been decided to adopt a procedure similar to that followed in other technical societies; namely, to let each technical committee be responsible for the definition of terms covering its own field. As a first step in this work, it is felt that the technical committees should insure the existence of proper definitions for all technical terms used in already existing American Standards sponsored by the SMPTE." The responsibility for correlating this nomenclature activity has been assigned to the Standards Committee. The actual correlating function is to be handled by a Nomenclature Subcommittee headed by Calvin Hotchkiss.—*Henry Kogel*, Staff Engineer.

The Color Plates in the December Journal

A good deal of interest has been shown in the color plates that accompanied the paper "Improved Color Films for Color Motion-Picture Production" by W. T. Hanson, Jr., and W. I. Kisner, published in the December 1953 *Journal*. The color plates were supplied by Eastman Kodak ready for binding into the *Journal*. They were made by the Kodak Ektalith process, which has been developed by the Eastman Kodak Co. to meet the demand for low-cost color printing in quantities of only a few thousand.

The process is based on the use of 35mm Kodachrome slides, although the same methods are applicable to all sizes and types of originals. Three colors are used for printing instead of the usual four. (For the *Journal* illustrations an additional printing plate was used to print the figure titles in black.) The color separation negatives are printed onto a Kodak Ektalith Sheet, which is a metal plate coated with a layer of a surface-hydrolized cellulose ester, sensitized with a solution of ammonium bichromate. The smooth, grainless surface of this plate, combined with the use of the right type of inks, makes possible the sharp printing of 266-line halftones. (Most periodical illustrations are as coarse as 110- or 120-screen.)

Most of the Ektalith color illustrations are printed on a Multilith Duplicator; however, the techniques used may also be applicable to larger-press operation. All registration, with the exception of a final small adjustment of the press, is achieved by purely mechanical means.

Fuller information about the process can be found in the following:

Walter Clark, "Cellulose acetate offset printing plate," Proceedings of the 2nd Annual Meeting, Technical Association of the Lithographic Industry: 115–118, 1951.

H. C. Staehle, "A simplified system of color printing," Proceedings of the 4th Annual Technical Meeting, Technical Association of the Graphic Arts: 143–150, 1952.

Pacific Coast Meeting

A meeting of the Section was held on December 15, 1953, at the Paramount Studios in Hollywood. Attendance was 285, although space limitation made it necessary for members to make reservations.

Carl Lesserman of Telemeter Corp. discussed the technical and economic phases of the Telemeter system of subscriber television, particularly with relation to the experimental telecast recently made at Palm Springs, Calif.

A method of subjective stereophonic reproduction from optical sound tracks was described by Louis Mesenkop, Assistant Sound Director at Paramount, who demonstrated the method with selections from *War of the Worlds*. Comparisons were shown on single and double photographic tracks switched to the three reproducing channels by means of the Dorsett system of control tracks in the sprocket-hole areas.

Loren Ryder, Sound Director and Head of Engineering at Paramount, gave a technical and economic appraisal of current technical advances, with particular relationship to the effects they may have on the future of motion pictures and television.—*E. W. Templin*, Secretary-Treasurer, Pacific Coast Section, c/o Westrex Corp., 6601 Romaine St., Hollywood 38, Calif.

SMPTE Lapel Pins

The Society has available for mailing its gold and blue enamel lapel pin, with a screw back. The pin is a ½-in. reproduction of the Society symbol—the film, sprocket and television tube—which appears on the *Journal* cover. The price of the pin is $4.00, including Federal Tax; in New York City, add 3% sales tax.

Book Reviews

Die Lichtverteilung im Grossen in der Brennebene des photographischen Objektivs

By Dr. Ernst Wandersleb. Published (1952) by Akademie-Verlag GmbH., Berlin NW7, Schiffbauerdamm 19. i–xiv + 125 pp. 49 illus. 11 tables. 6¾ × 9¾ in. $4.80.

The author investigates the distribution of light in the focal plane of a photographic objective and especially the factors contributing to the intensity variation from the center of the picture to the border.

The factors contributing to the decrease of illumination are: First, the $\cos^4 w$ law, which gives the natural decrease of light. The angle w in this formula is the angle which the principal ray of the bundle forms with the axis on the object side. Second, there is the influence of distortion where it is found that barrel distortion has a favorable effect and pincushion distortion an unfavorable effect with respect to the amount of light received. Third, there is the vignetting factor, which comes from the fact that the apertures of the single lenses may not be sufficiently large, so that some of the light coming from an off-axis point may be cut out. Fourth and fifth, there are reflections at the glass-air surfaces and absorption in the glass which may further reduce the amount of light emerging from the objective.

The author investigates in great detail all these factors and their frequently erroneous treatment in the literature. Of special interest to the reader may be the chapter in which the author discusses and refutes the claim of the inventors of the so-called "cycloptic" systems, which were thought to overcome the $\cos^4 w$ law of light decrease because of the fact that the exit pupil in such a system is at infinity.

The book contains a large amount of theoretical and experimental material with respect to the subject. In the later chapters the author discusses also the "false light," which is not image-forming, but which may very well change the image contrast considerably. He calculates, in particular, the amount of light which comes from double reflection at two glass-air surfaces. Of great interest is the author's suggestion for separating false and image-forming light by looking at the image through a cystoscope, which, because of its length, "sees" only the direct light.

The book contains the analysis of the light-loss in a large number of typical optical systems. The excellent drawings and photographs deserve special mention and the publisher is to be commended for the clear print and the quality of the illustrations.—*Max Herzberger*, Research Laboratories, Eastman Kodak Co., Rochester 4, N.Y.

Electronic Measurements, 2d Ed.

By Frederick Emmons Terman and Joseph Mayo Pettit. Published (1952) by McGraw-Hill, 330 W. 42 St., New York 36. i-xiii + 683 pp. + 8 pp. Author Index + 15 pp. Subject Index. 448 illus. 6 × 9 in.

The first edition, *Measurements in Radio Engineering*, has been so extensively revised and expanded that *Electronic Measurements* may more reasonably be considered a new book than a second edition. *Electronic Measurements* is no compendium of electronic measuring techniques nor is it intended as such. It is, rather, a well-organized textbook devoted to the measurement of electrical quantities and constants in the frequency range of direct current up through the microwave region with the unaccountable exception of the subaudio range. The chapters on "Laboratory Oscillators" and "Generators of Special Waveforms" are unusually good and add much to the value of this book for reference uses. The figures are numerous — they average about two to every three pages — and very well done.

To write a book on measurements without straying too far into the closely allied field of instrumentation is a difficult task. The authors have succeeded admirably in treating fundamental measuring techniques without undue concern with instrument details. There are, of course, omissions. An ever present need to conserve text space militates against the mention of infrequently used techniques such as, for example, the measurement of voltage with the electrostatic meter or the alternating-current potentiometer. Specific footnote references might well be used to draw attention to those methods of limited practical usefulness which are illustrative of basic principles.

Members of this Society, with their special interests in the audio and video fields, will note a number of omissions. There is no mention of wave filters or of the precautions necessary when measuring their transmission characteristics although transmissions lines are discussed at some length. The chapter on waveforms has a good discussion of the fundamental-suppression method of distortion measurement but no reference to the fundamental-balance method. Several techniques of wave analysis receive well merited attention yet the method of simultaneous analysis by tuned circuits or tuned reeds goes unmentioned. The old reliable "gain-set" method of measuring amplifier gains is not described though similar techniques of lesser precision are explained. Rather surprising in view of the space devoted to the SMPTE method of intermodulation measurement is the omission of the cross modulation method (XM) of measuring distortion, for the XM test is also an American Standard. The CCIF method described is, of course, the equivalent of the XM method; both have the same limitation, as normally used, of measuring only even order distortion.

These sample criticisms are of minor importance in relation to the book as a whole. This reviewer, having very limited knowledge of microwave techniques finds the sections dealing with microwave measurements very satisfactory. A specialist in microwave techniques would probably find the coverage of audio and video measurements equally satisfactory. As a text for use in conjunction with classroom or laboratory work *Electronic Measurements* is highly recommended. The engineer working in fields outside of his specialty will find this text a valuable source book. It is replete with references, many of them to recent publications. This is an especially desirable feature for one can always trace the development of a subject backward in time if a good recent reference is available.—*W. K. Grimwood*, Research Laboratories, Eastman Kodak Co., Rochester 4, N.Y.

Television, A World Survey

Published by UNESCO. 175 pp. $1.75.

This report covers 45 countries and territories. In 20 of these, public broadcasts are on the air; 8 are carrying out technical broadcast experiments; and in the other 17, governments or private organizations are taking active steps to introduce television. The study gives detailed information on the history of television in each country surveyed, its structure and organization, its source of revenue, the technical facilities which are available or planned for the future, programming and reception, the number and characteristics of transmitters, and other subjects such as color television and the training of personnel for new stations. A final section describes United Nations television activities.

A comparative table of countries having regular or experimental broadcasts lists the number of television stations in operation, the estimated number of receivers, the potential audience, date of first broadcast and other information. Another table deals with countries where technical experiments are under way, and a third table lists countries planning the introduction of television. Copies can be obtained from the UN Bookshop or from Columbia University Press, 2690 Broadway, New York 27.

Television Factbook, No. 18

Published (January 15, 1954) by Radio News Bureau, Wyatt Bldg., Washington, D.C. 374 pp. 8⅛ × 11 in. $3.00. 1954 TV map 43 × 29 in. $1.00.

The latest in this semiannual reference series brings up to date statistical tables summarizing 1953 and preceding years' FCC, PIB and other reports on network and station revenues, expenses, etc.; set and tube production, sales and shipments; and financial data on leading TV-radio-electronic manufacturers.

Also included are the usual data on TV stations (150 more since the last edition—reviewed in September 1953 *Journal*), networks and personnel, and directories of advertising agencies, national sales representatives, TV program sources, FCC, attorneys, consulting engineers and other consulting services, major electronic laboratories, community antenna systems, theater television installations and firms, market research organizations, trade associations, labor unions, and bibliographies of the literature and periodicals in the field.

The accompanying map shows all TV cities, existing and projected AT&T and private network facilities, all cities peculiar to the TV allocation plan, and all other cities over 10,000 population.

3 **SOUND MAGAZINES,** to be noted since the Journal of the Audio Engineering Society was initiated a year ago, are:

International Sound Technician, an illustrated monthly published by International Sound Technicians, Local 695, IATSE, has now been appearing since early in 1953. Devoted to developments and activities in the field of sound recording, the contents cover a very wide range of material, from technical papers through more popular "how to" articles to news items about events and personalities in the industry. Subscription rates are $2.50 per year or $5.00 for three years.

Revue du Son is a French monthly journal concerned with every aspect of professional sound recording and reproduction. Compiled by a distinguished board of editors and under the technical direction of Lucien Chretien the material is on a high technical level and representative of the latest progress in French research and industrial development. Each issue contains a substantial editorial by the editor, Maxime de Cadenet, and the technical papers are grouped under such headings as: Sound Reproduction, Sound Recording, Sound Films, Acoustics, Supersonics, Sound Systems, Circuits, Design. There are also book reviews, notices of new products, and news items about the industry. Subscriptions, which can be obtained from Editions Chiron, 40 rue de Seine, Paris 6, France, are 2100 francs per year, for 11 issues.

Tape and Film Recording, the first number of which appeared in December 1953, is a new illustrated bimonthly published by Mooney-Rowan Publications, Inc., Severna Park, Md. It is aimed primarily at the amateur tape-recorder enthusiast and is made up of "how to" articles, New Products, Questions and Answers, Consumer Reports on new equipment, etc. A year's subscription (6 issues) costs $2.00.

Photo-Lab-Index, 14th Lifetime Edition, pubished by Morgan & Lester, 101 Park Ave., New York 17, is the 1954 issue of this standard reference work. All phases of photography and related fields are included in 24 separate sections: Ansco, Ilford, Gevaert, Dufaycolor, Du Pont, Eastman Kodak, Haloid, Film Data, Filter Data, Illumination, Photo Papers, Weights and Measures, Chemicals, Cine Data, Darkroom, Color Data, Optics, Defects in Negatives and Prints, Transparencies and Slides, Copying, Photomechanical Processes, Bibliography, Photo-Words, Television. Photo-Lab-Index has 1348 pages in a looseleaf binder and sells for $17.95. Quarterly supplement subscriptions are available direct from the publishers only, at $3.00 per year.

Slides and Opaques for Television is a new pamphlet prepared by the Eastman Kodak Co. for inclusion in the Kodak Photographic Notebook. It describes the various types of photographic stills that are used in television and discusses the problems of safe area, tonal range, restricted range, lighting, subject, photographic processing, distribution of tones, color sensitivity and visibility standards involved in the preparation of artwork. Information is also given on copying equipment, exposure, lighting and handling of materials in the actual making of opaques and slides. Members can obtain copies of this pamphlet by applying to the Motion Picture Film Dept., Eastman Kodak Co., Rochester 4, N.Y.

Current Literature

The Editors present for convenient reference a list of articles dealing with subjects cognate to motion picture engineering published in a number of selected journals. Photostatic or microfilm copies of articles in magazines that are available may be obtained from The Library of Congress, Washington D.C., or from the New York Public Library, New York, N. Y., at prevailing rates.

American Cinematographer

vol. 34, Oct. 1953

"Penthouse" 4-Track Sound Reproducers (p. 479) *R. Lawton*

MGM's Variable Wide Screen Projection Lens (p. 484) *F. Foster*

Simplified Single-Film System for 3-D Exhibition (p. 485) *A. D. Roe*

Film Splicing Without Cements or Adhesives (p. 486) *L. A. Herzig*

The Pan Cinor-Variable Zoom Lens for 16mm Cameras (p. 490) *A. Rowan*

vol. 34, Nov. 1953

Extension Tubes in Cine Photography (p. 545) *J. Forbes*

Wide Screen for 16mm Presentations (p. 558)

vol. 34, Dec. 1953

Is 3-D Dead . . . : (p. 585)

Paramount's "Lazy-8" Double-Frame Camera (p. 588) *J. R. Bishop and L. L. Ryder*

Electronic Recording of Pictures on Tape (p. 596) *A. Rowan*

Closeup Photography with 16mm Single-film Stereo Systems (p. 598) *E. Wildi*

Animated Movies with Paper Cutouts (p. 600) *G. W. Cushman*

Journal of the Audio Engineering Society

vol. 1, no. 3, July 1953

A Variable-Speed Distributor System for Synchronizing Out-of-Sync Pictures and Sound Tracks (p. 241) *H. M. Tremaine*

The Amplifier and Its Place in the High-Fidelity System (p. 246) *H. H. Scott*

Bild und Ton

vol. 8, Dec. 1953

Herstellung von Schwarzweiz-Kopien von Agfacolor-Negativen (p. 354) *W. Brune*

Die Gestaltung des Farbentwicklungs-Laboratoriums (p. 355) *C. Michel*

Farbaufnahmen auf Agfacolor-Umkehrfilm (T) bei Leuchtstofflampenlicht (p. 359) *G. Wendel*
Entwicklungsstand der Bildprojektoren und Bildtonanlagen für 16-mm-Film in der Sowjetunion (p. 365) *G. Pierschel*

British Kinematography

vol. 23, no. 3, Sept. 1953

The Application of Television for Underwater Use (p. 58) *C. Hirsch, G. T. Syminton and N. R. Phelps*

vol. 23, no. 4, Oct. 1953

Water Effects (p. 86) *R. L. Hoult*
The Production of Trailer (p. 98) *E. Harris*

vol. 23, Nov. 1953

The Practical Problems of 3-D Presentation (p. 115) *G. E. Fielding*
2-D and 3-D Trends in the Current Cinema (p. 124) *R. J. Spottiswoode*

Electronics

vol. 26, Nov. 1953

Color-Television Converter for Cable Networks (p. 132) *J. G. Reddeck and H. C. Gronberg*

vol. 26, Dec. 1953

Sound-Projector Amplifier for 16-mm Motion Pictures (p. 194) *J. A. Rodgers*

vol. 27, Jan. 1954

Camera Adapter for TV Receivers (p. 141) *L. E. Flory, W. S. Pike and G. W. Gray*

General Electric Review

vol. 56, Nov. 1953

Color Television — Today and Tomorrow (p. 19) *W. R. G. Baker*

Home Movies

vol. 20, Dec. 1953

"Panavision" . . . New Wide Screen System (p. 510) *H. Provisor*

International Photographer

vol. 25, Dec. 1953

CinemaScope Makes Under-Water Debut (p. 5) *T. Gabbani*

International Projectionist

vol. 28, Oct. 1953

Film Industry Eyes New Stereo Sound (p. 7) *T. L. Burnside*
Stereoscopic Projection and Photography. III. History and Projection Techniques (p. 10) *R. A. Mitchell*
CinemaScope Wrecks Records (p. 16) *J. Morris*
Lens Chart for Wide Screens (p. 17) *M. D. O'Brien*

vol. 28, Dec. 1953

Recent Projection Advances in Europe (p. 7) *R. A. Mitchell*
Film Splicing for 3-D and CinemaScope (p. 11) *J. Morris*
RCA's "Magnetic Movies" Portend New Industry Revolution (p. 22) *F. Hodgson*

An Improved Carbon Lamp for 3-D and Wide Screen (p. 29) *E. Gretener*
Panaphonic System is Shown on Coast (p. 37)

Kino-Technik

no. 7, Sept. 1953

Schmalfilmprojektoren hoher Qualitat und Leistung (p. 246) *H. Atorf*
Neue Wege zum Stereo-Schmalfilm bei Halbbildanordnung (p. 249) *H. Atorf*
Entwicklung und Stand der Magnettonband-Technik (p. 252) *Jarczyk*
Betrachtungen über Schmalfilmaufnahmeobjektive verschie dener Brennweiten (p. 254) *W. Albrecht*
Philips-Schmaltonfilmprojektor 16mm Cinema Typ EL 5000 (p. 256)

no. 10, Oct. 1953

Hochfrequenzkamera für 3,500,000 Bilder je Sekunde (p. 287) *H. Hintze*
Askania-Projektoren für 3-D-und Cinemascope-Filme (p. 289) *L. Busch*
Gute Stereowiedergabe bie einwandfreier Polarisation (p. 290)
Tret'e Izmerenie—"Die 3. Dimension" im Sowjetfilm (p. 293) *W. Selle*
Praktische Erfahrungen bei Farbaufnahmen mit Agfacolorfilm (p. 297) *W. Behrendt*

vol. 7, Dec. 1953

Cinemascope-Synchronisation in 3-Kanal-Stereophonie (p. 341) *H. C. Wohlrab*
Gute Stereowiedergabe bei einwandfreier Polarisation (p. 343) *E. Kasëmann*
Tret'e Izmerenie—"Die 3. Dimension" im Sowjetfilm (p. 344) *W. Selle*
Rundgang durch die italienischen Ateliers (p. 350) *E. Monachesi*
Praktische Erfahrungen bei Farbaufnahmen mit Agfacolorfilm (p. 355) *Dr. Behrendt*

Motion Picture Herald

vol. 193, no. 10, Dec. 5, 1953

RCA Shows its Magnetic Film (p. 12) *G. Schutz*

Motion Picture Herald (Better Theatres Sec.)

vol. 193, Nov. 7, 1953

Advantages of Magnetic Sound (p. 14) *G. Gagliardi*

vol. 193, Dec. 5, 1953

Adjusting the Seating Plan to Wider Pictures (p. 12) *B. Schlanger*
How to Determine Lamp Type Required for Wider Pictures (p. 29) *G. Gagliardi*

vol. 194, Jan. 9, 1954

3D . . . Its Progress and Its Prospect (p. 12)
A Functional Setting for the "Wide-Screen" Picture (p. 18) *B. Schlanger*

Photorama

vol. 10, no. 10, 1953

Colour According to the Rules and . . . Against Them (p. 287) *J. Lauwers*

RCA Review

vol. 14, Dec. 1953

Particle Counting by Television Techniques (p. 546) *L. E. Flory and W. S. Pike*

Aperture Compensation for Television Cameras (p. 569) *R. C. Dennison*

Radio & Television News

vol. 50, Oct. 1953

TV Tube Substitutions (p. 50) *W. H. Buchsbaum*

Color TV (p. 51) *W. R. Feingold*

New TV Intermittent Checker (p. 56) *J. Racker*

Know Your 1954 General Electric TV Receivers (p. 63) *J. Najork*

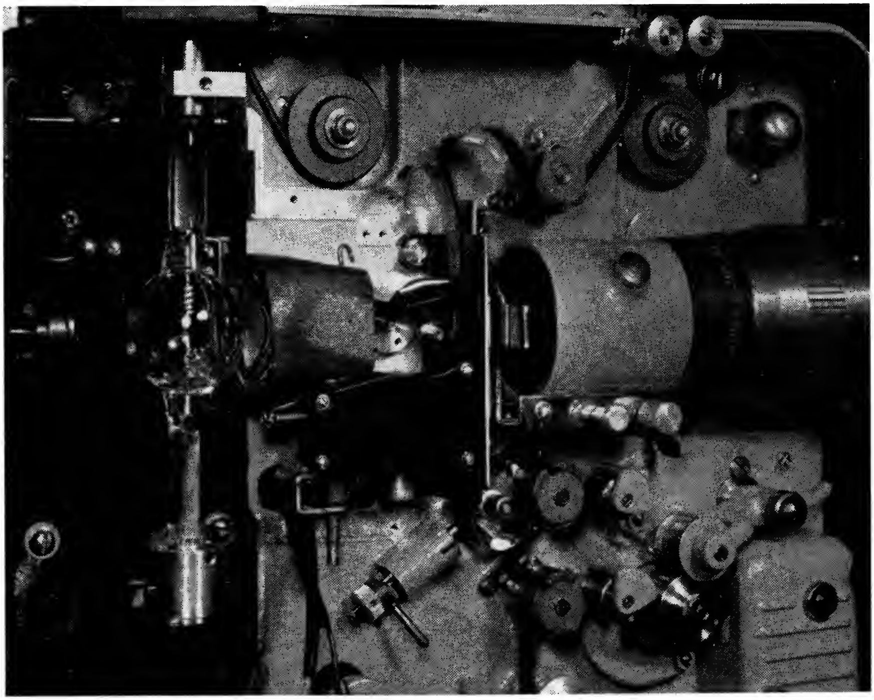
New Products

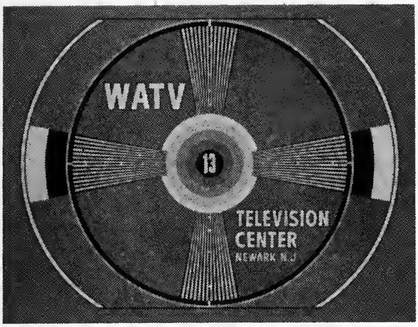
Further information about these items can be obtained direct from the addresses given. As in the case of technical papers, the Society is not responsible for manufacturers' statements, and publication of these items does not constitute endorsement of the products.

A new light source, claimed to be five times brighter than conventional bulbs and designed to function simultaneously as light and shutter, has been announced by De Vry Corp., 1111 W. Armitage Ave., Chicago, Ill. This development makes possible a shutterless motion-picture projector. It is also intended to meet unusual demands for brightness level such as are met with in 3-d projection and color television.

Ordinary projectors operate with 48 light fields in 24 frames/sec of film, giving each frame two light fields, with the shutter responsible for a loss of up to 50% of the available light. Since the new source eliminates the shutter, all the available light can be used. It consists of a xenon gas, quartz-enclosed arc lamp, specially designed to give intermittent fields of light to each frame as the film passes through the projector. Instead of the ordinary two fields, however, each frame receives five fields. The film is synchronized so that the pulldown on each frame occurs during the 4.5 msec of darkness between each flash. A standard shuttle is used for the pulldown. A full description of this new development is to be given at the SMPTE Spring Convention in Washington, D. C., May 3–7.

A new **station identification slide** is offered by Loucks & Norling Studios, Inc., 245 W. 55 St., New York 19. As the illustration shows, the call letters, channel number, address and any other information that may be wanted are fitted into





a resolution pattern. The price of a 2 × 2-in. slide, made up to include the customer's information, is $100. Additional slides cost $5.

RTMA television resolution charts available from Loucks & Norling are:

Slides (Mounted in glass)	
2 × 2 in., image 0.85 × 1.13 in....	$ 3.75
2 × 2 in., image 0.92 × 1.22 in....	3.75
3¼ × 4 in., image 2.25 × 3.0 in...	5.00
Motion-Picture Films (safety stock)	
35 mm Silent (no sound-track signal), 250 ft.	40.00
35 mm 400-cycle signal optical sound track, 250 ft	50.00
16 mm Silent, per unit of 100 ft . .	17.50
16mm 400-cycle signal optical sound track, 100 ft	25.00
Film Strips (safety stock, 35 mm)	
Unit of 40 frames [2½ ft in length) .	4.75

The Angenieux Retrofocus 35mm Lens, a new lens for television, is announced by Ponder & Best, Telelens Division, 814 North Cole Ave., Hollywood 38, Calif. Featuring a 64° angle of view, this high-resolution lens is intended to fill the need for a quality lens of short focal length. It is supplied in a focusing mount with iris diaphragm and having an effective aperture of *f*/2.5.

Employment Service

These notices are published for the service of the membership and the field. They are inserted for three months, at no charge to the member. The Society's address cannot be used for replies.

Positions Wanted

Wanted, Motion-Picture Industrial Engineer: 8 yrs planning plant expansion and improvement projects of film laboratories, including equipment procurement, contracting, expediting, bill-of-materials control, machine design, material handling, floor-plan layout, utilities. Familiar with cinematography, sensitometry, color principles, printing problems, mfg. processes. MIT-trained in mech., elec., indus. engineering. Esp. interested in Service Dept., producer liaison, or TV applications. • Phone or write: F. L. Bray, DuArt Film Laboratories, 245 W. 55 St., New York City, PLaza 7-4580.

Motion-Picture Television Technician: 10 yr intensive skill and know-how related to 16-35mm cinematography, animation, recording (optical, tape, disk), editing, laboratory processing practice (black-and-white, color); also kinescope recording techniques; self-reliant; inventive; relocate if required; write: CMC, c/o Penning, 435 E. 74th St., New York 21, N.Y.

Motion-Picture Laboratory Technician: 3½ yr experience as motion-picture laboratory technician in black-and-white and color. Emphasis has been on color processing with both Ansco and Eastman color films. Experience in managing production and supervising personnel. Desire position that can make the most of above experience. Write; Bryan Allen, 812 Vermillion St., Gary, Ind.

Motion-Picture Cameraman: Retiring from Naval Service. 15 yr experience in camera operation, printing, processing, adm. and supervision of production crews. Desires position in TV, educational or industrial field, inaugurating a motion-picture program. Available after May 1954. Prefer West Coast. Write: W. W. Collier, 422 W. Jackson Ave., Warrington, Fla.

Electronics Engineer: B.S.E.E., 3 yrs chemical engineering, 2 yrs graduate work in physics. Currently working on Masters Degree. Engaged in gaseous electronics research, experienced in design and development of electronic instrumentation, installation and operation of automatic recording temperature control systems, vacuum system technique, maintenance and repair of all types of electronic equipment. 4 yrs retail business experience. Possess ability to write clear, concise reports. Interested in the motion picture, both artistically and technically. Desire position with organization in Los Angeles area preferably engaged in motion-picture production. Expect to be in Los Angeles area in late summer this year. Request interview. Member, IRE, SMPTE, Fla. & Nat. Soc. of Prof. Engs. Registered Engineer in Training State of Florida. Age, 28; unmarried. Write: Berel David Solomon, Box 274, Univ. Station, Miami, Fla.

Positions Available

Photographic Engineer: Wanted for design and development work involving application of film and associated equipment to monochrome and color TV systems. Prerequisites are BS or equivalent, and experience in at least one of the following motion-picture fields: (a) TV film applications, (b) processing laboratory design and operation, (c) camera and projector design or (d) sensitometry and densitometry. Please send résumé to Personnel Dept., CBS Television, 485 Madison Ave., New York 22, N.Y.

Sales Management Engineer: To head division manufacturing single optical track stereo sound system. Already adopted by major studio. Position requires knowledge of theater sound systems here and abroad. Reply to: Fairchild, Rm. 4628, 30 Rockefeller Plaza, New York 20, N.Y.

Engineer: To direct engineering of flying-spot TV projector with millisecond pulldown mechanism. Mechanism already developed and working. Reply to: Fairchild, Rm. 4628, 30 Rockefeller Plaza, New York 20, N.Y.

Wanted — Consultant technician: Thorough knowledge of Houston continuous double-head printer, Houston developing machines, Bell & Howell printers and Debrie Matipo step printer. Must put machines in running order and train operating personnel. Usual per day rate and plane fare to Puerto Rico. Address replies to R. J. Faust, Chief, Cinema Section, Dept. of Education, Commonwealth of Puerto Rico, Division of Community Education, P. O. Box 432, San Jaun, Puerto Rico.

Permanent Position: Open for versatile 16mm cameraman familiar with all phases of industrial production. Write McLarty Picture Productions, 45 Stanley St., Buffalo 6, N.Y.

Meetings

Radio Engineering Show and I.R.E. National Convention, Mar. 22–25, Hotel Waldorf Astoria, New York

Optical Society of America, Mar. 25–27, New York

The International Sound Track Recording Convention has been announced by the Association of Radioelectricians, 10 Ave. Pierre Larousse, Malakoff (Seine), France, to be held in Paris, April 5–10, 1954, on sound-track recording processes and their extension to other fields of application. Radio and television networks and the motion-picture industry will participate with technical papers, an exhibition of equipment, and tours of plants and technical centers. Problems of standardization will be discussed.

The Calvin Eighth Annual Workshop, Apr. 12–14, The Calvin Co., Kansas City, Mo.

International Symposium on Information Networks (information from Microwave Research Institute, Polytechnic Institute of Brooklyn, 155 Johnson St., Brooklyn 1, N.Y.), April 12–14, Engineering Societies' Building, New York

Society of Motion Picture and Television Engineers, Central Section, Spring Meeting, Apr. 15, The Calvin Co. Sound Stage, Kansas City, Mo.

75th Semiannual Convention of the SMPTE, May 3–7, Hotel Statler, Washington

Society of Motion Picture and Television Engineers, Central Section (with Western Society of Engineers), May 13

Society of Motion Picture and Television Engineers, Central Section (with Western Society of Engineers), June 10

American Institute of Electrical Engineers, Summer General Meeting, June 21–25, Los Angeles, Calif.

Acoustical Society of America, June 22–26, Hotel Statler, New York

American Physical Society, June 28–30, University of Minnesota, Minneapolis, Minn.

American Physical Society, July 7–10, University of Washington, Seattle, Wash.

Illuminating Engineering Society, National Technical Conference, Sept. 12–16, Chalfonte-Haddon Hall, Atlantic City, N.J.

Photographic Society of America, Annual Meeting, Oct. 5–9, Drake Hotel, Chicago, Ill.

American Institute of Electrical Engineers, Fall General Meeting, Oct. 11–15, Chicago, Ill.

76th Semiannual Convention of the SMPTE, Oct. 18–22, Ambassador Hotel, Los Angeles

77th Semiannual Convention of the SMPTE, Apr. 17–22, 1955 (next year), Drake Hotel, Chicago

The International Commission on Illumination is to hold its next international conference in Zürich, Switzerland, June 13–22, 1955 (*next year*). Offers of papers should be addressed to the Chairman of the Papers Committee (A. A. Brainerd), 1015 Chestnut St., Philadelphia 7. Manuscripts must be in the hands of the Central Bureau between Oct. 1 and Dec. 31, 1954.

78th Semiannual Convention of the SMPTE, Oct. 3–7, 1955 (next year), Lake Placid Club, Essex County, N.Y.

Evaluation of the Steadiness of 16mm Prints

By A. C. ROBERTSON

A satisfactorily bright and steady image of large size can be obtained from the projection of a 16mm print if good film, a good camera, a good printer and a good projector are used.

It has been shown by a trade survey that 16mm prints differ appreciably in steadiness. This was learned by viewing prints made in various laboratories from a 16mm reversal original, or from a 35mm negative made from the same scene. The steadiness of some prints approached the quality of the 16mm original, as was found by the examination of the prints made especially for this survey. It was also noticed that the photographic quality of the prints varied over a wide range, comparable to the observed variation in steadiness.

Sixteen millimeter film started as an amateur product[1,2] and is often regarded as being only that. Actually one can project 16mm pictures in a small theater and get results which are almost indistinguishable from those one would obtain from 35mm equipment, as far as steadiness is concerned. The question to be discussed is this: How well do the prints now available conform to the requirements necessary to obtain the high standard of performance noted above?

Printing Processes

Sixteen millimeter professional prints can be made in many ways.[3,4] The methods are:

(A) By contact printing from a 16mm original;

(B) By optical printing from 16mm originals;

(C) By reduction printing from 35mm originals.

The processes are described schematically in Figs. 1, 2 and 3. These figures are adapted very largely from charts believed to have been assembled by E. A. Bertram for use by committees of the American Standards Association between 1941 and 1945.

These general schemes naturally do not describe the mechanical details of the operation of printing. The exact way the film is positioned in the printer is important in securing accuracy. Also, it is evident that the more positioning operations are used during the production of the print, the greater is the chance that the accumulated error will

Presented on April 30, 1953, at the Society's Convention at Los Angeles by A. C. Robertson, Manufacturing Experiments Div., Kodak Park, Eastman Kodak Co., Rochester 4, N.Y.
(This paper was received Feb. 19, 1954.)

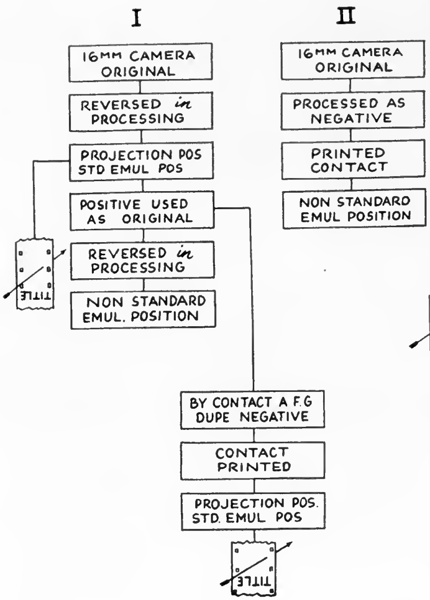


Fig. 1. Chart showing two schemes of printing 16mm camera originals by contact.

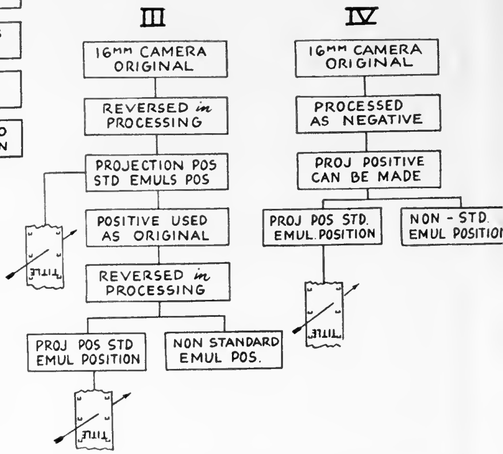


Fig. 2. Chart showing two schemes of printing 16mm camera originals by projection. Note that the operation of projection printing permits one to change emulsion position.

become large. Because of the need for accurate positioning, the dimensional uniformity of the perforations in the film and also the accuracy of the printers must be controlled, for they both have an important effect upon the steadiness characteristics of the finished prints.

These relationships obviously did not apply to the original amateur film, which was made by photographic reversal. Therefore, the film used in the camera was later used in the projector. The original amateur projectors matched the cameras as far as the location of the pulldown claw was concerned. Accordingly, the relationship called "cancellation" was present. When cancellation is present in the design of the camera and projector, most of the errors of perforating are prevented from producing unsteadiness.[5]

In the manufacture of prints there

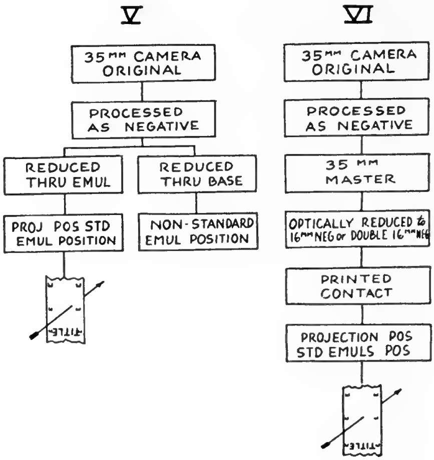


Fig. 3. Chart showing two schemes of printing 16mm release positives by optical printing from 35mm originals. Note that there is a choice of emulsion position.

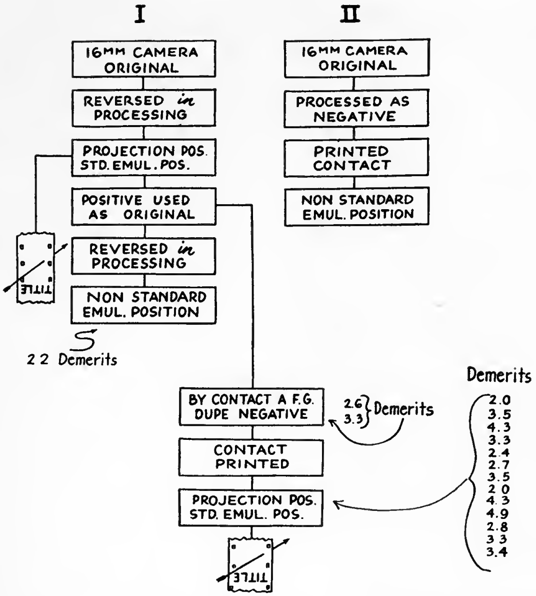


Fig. 4. Results of survey of contact printing operation encountered. There are 16 out of 24 total. The demerit ratings have been added in three locations to this chart, which was given first as Fig. 1.

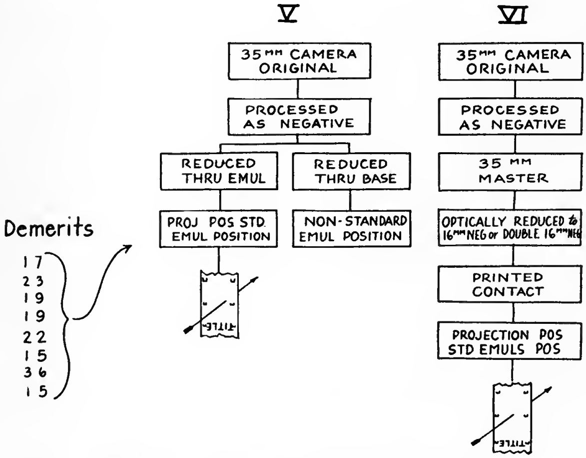


Fig. 5. Results of survey of optical reduction printing. There were 8 examples out of 24 total. Note that Process VI which uses contact printing from a reduced negative, was not used on the survey samples.

are printing operations, involving the use of several kinds of equipment, and cancellation is difficult to obtain, not having been provided for ahead of time, by the designer of a system or "package deal."

The simplest procedure is found in the making of a print from an original scene or subject. This requires two registration operations, one in the camera and one in the printer. This scheme is attractive because of the relative simplicity of the printing operation. Today, however, most laboratories do not make 16mm contact prints from an original. Generally a duplicate negative is made first.

One of the more complicated printing operations is to be found when a 16mm print is made from a 35mm negative by the 32mm process. Here we have the two positioning operations in the optical reduction printer. There is another positioning operation needed for the production of the 32mm duplicate negative, another for its printing on release stock and still another positioning operation when the film is divided into parts for final use.[6]

Survey of Trade Conditions

Everyone has noticed that some 16mm prints are steadier than others, but it is difficult to make this statement with assurance unless the prints under discussion are made and tested under comparable conditions. This chance seldom arises. We have been able to make prints which can be compared safely with one another through the cooperation of many people in the trade who worked cheerfully with the staff of the Motion Picture Film Department of the Eastman Kodak Company. This cooperative venture produced the 20-odd prints we were able to examine and measure.

A 16mm original was made on Cine Kodak Super-X Panchromatic film in a Maurer camera provided with a specially selected lens. A 35mm negative was made almost simultaneously with a Mitchell camera, using equipment like that ordinarily employed in many studios. The subject matter consists of material which we hope would be acceptable to people making either documentary or entertainment films. The architectural scenes are very critical and motion can be detected in them rather easily. The portrait scenes are less critical, having few sharp regular lines near the edges of the picture. Accordingly, if any movement can be detected, it is certain that the picture unsteadiness is excessive.

Observe in the upper left portion of Figs. 4 and 5 an indication of the number of processes to be in use at the time of the survey. In this survey there were received no examples of 16mm prints made by 1:1 optical printing methods (Fig. 2). Note that reduction printing from the 35mm negative is used in many laboratories (Fig. 5). However, we are not able to determine what fraction of the total footage used today comes from this, or other processes. It is thought that the continuous printers produce the greatest footage.

(At this point in the oral presentation a demonstration reel was projected.)

The first scene included in the demonstration reel came from the 16mm camera original from which many of the succeeding prints were made. The way in which the prints were assembled was such that there was a separation according to the location of the laboratories. Most people think that there is little difference between the geographical groups. Many other observers agreed with the jury ratings that we have obtained with Kodak jurors, which show that the prints made by optical reduction from the 35mm negative were very good. However, it must be noted that many of the contact prints made by the 16mm process were also very steady.

In a trade survey like this, where we did not have a number of prints made by each laboratory, we do not know how great the daily variation may be. We may have collected our samples on a "good" day or on a "bad" day for that laboratory. Accordingly, this survey does not give the final answer to the question "how one is to get the best possible print." The survey does show that steady prints are possible and can be made by different processes. It also shows just as definitely that some professional 16mm prints are distinctly unsteady.

The prints were rated for steadiness and these ratings have been added to Figs. 4 and 5, with arrows designating the printing process with which they are associated. These ratings are numerical and represent the average value of the opinions of three or four juries, each containing about six people. The jurors rated the film A for the best they had ever seen, and E for the worst they had ever seen, with appropriate values in between. The rating A was given a value of 1 demerit for arithmetic purposes and the rating E a value of 5 demerits. A demerit rating of 2.5 therefore has a letter rating between B and C.

It was noted that the photographic quality of the prints varies a great deal. This is something that we had not taken into consideration and therefore did not include any step wedges or the like in the subject matter.

Unsteadiness Meter

Some of these prints have been studied by the use of an unsteadiness meter that we have used but not described publicly as yet. This device gives us data that enable us to construct a cumulative frequency-distribution curve describing the movement of the image. It is rather difficult to say whether a method using the standard deviation obtained in this way (which is the root-mean-square error of the placement of the image) agrees exactly with a method using a rating obtained from jurors. Our experience shows the statistical measurement to be a useful thing in general.

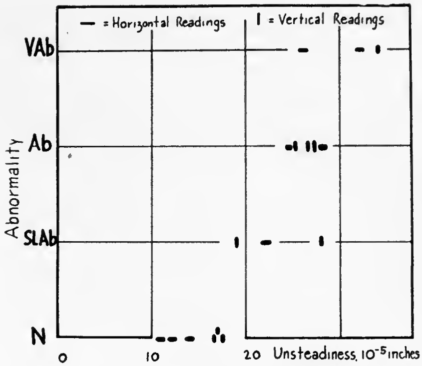


Fig. 6. Relationship between unsteadiness of prints and "normality" of the location-distribution curve.

In addition we have found in the past that when the distribution curve did not conform to the "normal" or Gaussian form that statisticians usually expect to encounter, it paid us to study the printing operation in detail. It was found that further investigation would generally reveal a few large errors in the film or equipment which had produced this abnormality. The abnormality is designated in Fig. 6 as VAb for very abnormal, Ab for abnormal, SlAb for slightly abnormal and N for normal on the basis of a graphical method. In this graphical method, the cumulative frequency-distribution curve was plotted on a Hazen grid (arithmetic probability paper) which is designed to change the curved shape of the cumulative curve into a straight line. The departure from the expected straight line was observed and given a rating. When the departure was great, the rating was designated Ab. Smaller departures were given appropriate ratings. These values are purely subjective and qualitative. They are not related to the Pearsonian skewness values often used by statisticians, which could not reasonably be calculated for the small number of observations involved. Three or four of the prints had high values for "abnormality" and steadiness and would have been examined in detail had this been a laboratory study, and not a trade survey. Also the equipment used in making the prints would have been scrutinized. Obviously, the most unsteady prints have a few large sources of error, which distort the "normal" curves that are associated in our thinking with a relatively large number of small sources of error.

In conclusion, a trade survey has shown that professional 16mm prints differ appreciably in both steadiness and photographic quality. Not enough data were available to determine whether the process of making prints on a continuous sprocket printer is fundamentally better (or worse) than the use of a step printer. More tests would be needed, particularly repeat tests, which would give some idea of the uniformity of the printing operation in a given laboratory. Note that some of the prints from both systems were steady: it is the task of the film user to make sure he gets the kind of prints he wants.

Acknowledgments

This survey required a great deal of help, and I wish to thank the people in the industry for their cooperation and my many colleagues in the Kodak organization for their cheerful aid in getting the prints made. Special thanks are due W. H. Groth and D. F. Botkin for their help in rating the samples and assembling the data.

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Stereoscopic Perceptions of Size, Shape, Distance and Direction

By D. L. MacADAM

Most of the distortions perceived in stereoscopic pictures are caused by false perspective. False perspective cannot be corrected by variation of the camera interaxial separation. Parallax movements, which result from head movements in ordinary experience, are lacking in stereoscopic pictures, and are replaced by perverse twists of the scene. This lack is felt as a real shortcoming of stereoscopic motion pictures, and is best masked by frequent movement of the camera during shots.

About the year 1500 Leonardo da Vinci wrote that it is impossible for a painter to recreate a scene on canvas, because at best he could only show it as it appeared from one point of view. But, Leonardo pointed out, we ordinarily see every scene simultaneously from two different points of view, by means of our two eyes.* From the differences caused by the difference of point of view, the sense of space and distance arises. Really, nothing need be added to that explanation. Our minds are such that the sense of space and depth naturally aroused by a scene can be produced artificially by showing to each eye a picture taken from the point of view that that eye would have occupied had the observer been present in person. True stereoscopy does just that, and no abstruse arguments or geometrical constructions are needed to prove it. Nor would they be adequate to prove the fact, if it were not a matter of experience.

However, study of many stereoscopic pictures, and consideration of comments and discussions concerning them, indicate that what is wanted is not merely an explanation of why we get normal depth perception from binocular vision and from accurate stereoscopy, but rather why we see the distortions that are apparent when liberties are taken with the fundamental principle explained 450 years ago by Leonardo. Obviously, if we show the two eyes views of a scene that they could not have gotten simultaneously from any possible points of view, distorted perceptions must be expected. The problem is to classify the violations of Leonardo's rule,

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* Quoted and discussed in reference 1, pp. 9 and 10.

to determine the penalty for each, and to learn whether two wrongs can make a right in stereoscopy, that is, whether one kind of variation from natural vision can compensate for another.

Perception

Perception is our awareness of the things around us. Perception is based on more or less unconscious interpretations of our sensations, and is immediate, vivid and impelling. Perception is ordinarily a reliable indication of the world around us. But when the presentations of our sense organs are disturbed, our perceptions can be grossly in error, although they remain just as insistent and convincing as ever. Stereoscopic photography is merely the most recently popular device for tampering with our senses and distorting our perceptions.

In stereoscopic photography, two pictures are taken simultaneously, from slightly different points of view. The separation of the points of view, commonly called the *interaxial separation*, in this article will usually be called the *camera separation* to distinguish it clearly from the *projector separation*, which ordinarily has only minor influence on distortions, and which will not be discussed in this article. The differences between the two pictures taken with a stereoscopic pair of cameras are called *binocular disparities*. By some device, such as polarization of the two images in mutually perpendicular directions, and the use of polarizing spectacles by each member of the audience, his right eye views only the picture taken with the righthand camera, and his left eye views only the picture taken with the lefthand camera. A vivid sense of depth is thus produced. Whether, and under what conditions, normal perceptions of depth, size, shape and distance are produced constitute the principal subject of this article.

Serious distortions can be avoided only if stereoscopic pictures are shown with nearly correct perspective. That means that each person or object in the projected picture should fill just about the same angle at the eyes of the observers as he did at the camera. There seems to be a liberal tolerance on this requirement, so that the familiar rule that the focal length of the projector should be twice the focal length of the camera is satisfactory for most theaters. However, in the past, this rule has been violated frequently. The resulting false perspective is often noticeable, but not objectionable, in flat motion pictures. The purpose of this article is to emphasize that such false perspective is much more noticeable and objectionable in stereoscopic pictures.

Monocular Clues for Depth Perception

When viewing ordinary motion pictures, we perceive depth by means of a number of monocular clues. Among these are *overlay*, in which near objects overlap and hide more distant objects; *perspective*, in which near objects produce larger images than far objects of the same size; *aerial perspective*, in which contrasts are reduced and colors are degraded toward blue by atmospheric haze; *shadows*, which indicate distance and thickness by their relations to other objects and to each other; *parallax*, which is the apparent relative movement of objects at various distances, caused by head or camera movements; and *height*, whereby objects seen above others, in the absence of conflicting clues, are judged as being more distant.*

Figure 1 indicates the role of overlay and perspective in conveying the impression of depth and solidity. The central section is a map of two blocks, a wall, and the center of the camera lens. The more distant block is twice as high as the nearer block. At the top center of Fig. 1 is an outline drawing representing the picture obtained.

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* Reference 2, pp. 1070–1074, and reference 3, pp. 133–134.

For an observer just as far in front of the screen as the camera is shown to be in front of the nearest object, the perspective is correct. The observer gets a correct idea of the shapes and relative locations of the objects. If he recognizes any one of the objects in the scene and knows its size, then he perceives its distance correctly and therefore correctly perceives the distances and sizes of all the rest of the objects.

The drawing on the left shows the perspective, with overlap, obtained with a camera located twice as far away as previously. If the resulting picture is viewed so that the image of the foremost object subtends the same visual angle as previously, but twice as great an angle as it did at the camera, then false perspective results. The observer gets wrong ideas of the shapes and relative locations of the objects. If he recognizes the front object, he may perceive its front face as being the correct size, at the same distance as he formerly perceived it. But it and all other objects appear too thin, and too close together. At the right, the camera is shown at only one-quarter the original distance. If the resulting picture is viewed so that the front object subtends the same angle as previously, but one-quarter the angle it did at the camera, false perspective again results. If the observer recognizes the front object, he may perceive its front face as being the correct size, at the same distance as formerly. But it and all other objects will appear to be elongated in the direction away from him, and separated too far.

True and False Perspective

The picture at the top of Fig. 2 illustrates the effect of short camera distance on perspective and the resulting depth perception without stereopsis. The camera was 2 ft from the girl, and 12 ft from the man, but as printed and viewed at normal reading distance (10 in.), a girl of normal size must be visualized at about 6 ft from the reader, and the man

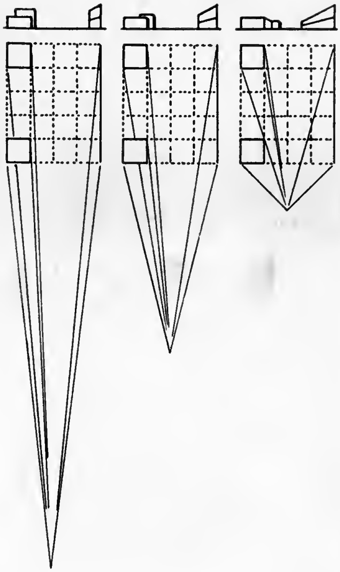

Fig. 1. Ground plans of three camera locations and (above) outlines of resulting perspectives of two blocks and a wall. The more distant block is a cube. The closer block is only one-half as high.

about 36 ft. Since the image of his head is about one-sixth as high as the image of the girl's head, a man of normal size must be visualized about 6 times as far away. His apparent distance is exaggerated by whatever factor the girl's apparent distance is increased by false perspective. The bricks and other architectural features of the building tend to reduce the exaggeration of distances, but false perspective distorts the shape of the bricks and of the building, as may be seen by comparison with the central picture in Fig. 2. The proper viewing distance at which the picture at the top of Fig. 2 would be seen in correct perspective is about 3 in.

The central picture in Fig. 2 was taken from a point of view 6 ft from the girl. Neither of the subjects had moved from the positions they occupied when the top picture was taken. The central

Fig. 2. Photographs of identical scene, taken with camera 2 ft, 6 ft and 36 ft from girl, and magnified to give equal images of girl. False perspective is evident in near and far shots (top and bottom). Perspective is correct only for middle picture. Stereoscopic presentation would make perspective distortions much more evident. Use of camera interaxial separation different from interocular separation cannot correct or compensate for false perspective.

picture in Fig. 2 is printed at such a size that the perspective is correct at the normal reading distance. Therefore, the girl appears about 6 ft from the reader, and the man about 16 ft, true to the original scene. The building, too, is perceived very much as it appeared to the cameraman.

The picture at the bottom of Fig. 2 shows the effect of excessive camera distance, resulting from the use of a telephoto lens. The camera was 36 ft from the girl and 46 ft from the man. Both were in the same locations as for the other two pictures. The bottom picture in Fig. 2 is printed at such a size that, for the usual reading distance, the girl appears 6 ft away. Since the distance of the man from the camera was only 28% greater than the distance of the girl, he cannot appear farther than 8 ft from the reader. Actually, because he is somewhat taller and heavier, he appears at least as near to the reader as the girl. The door, which was at least 45° from the frontal plane, as shown by the central picture, appears to be parallel to the frontal plane in the bottom picture, and the corner of the brick column directly over the center of the girl's right shoulder appears to be flattened to a plane. All of these are distortions caused by excessive camera focal length (or, which is the same thing, excessive magnification), which results in false perspective.

In a very deep-seated sense, "seeing is believing," and the human mind does the best it can to interpret the evidence of the eyes. *The front faces of all known objects are interpreted as being normal size*, so long as the visual evidence permits such an interpretation. This natural presumption, that the actual sizes of things do not depend on their distances, determines the distances at which objects portrayed in flat pictures are visualized. As a result, the three perspectives shown in Fig. 1 are perceived as if the ground plans were as shown in Fig. 3.

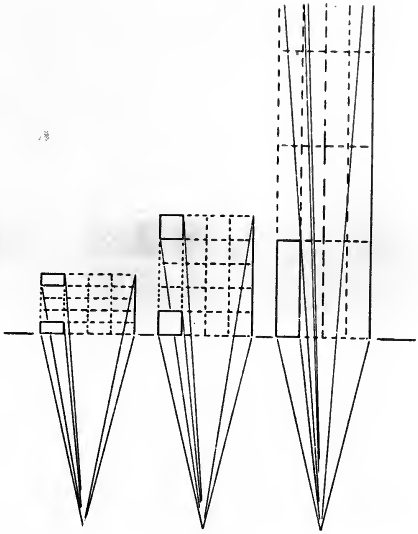

Fig. 3. Apparent ground plans of scene resulting from false perspectives shown in Fig. 1. All distances are determined by natural presumption that actual sizes of objects are not dependent on their distances. Screen location is shown by horizontal line extending to extreme right and left, in this and all subsequent diagrams.

Importance of Movement Parallax in Space Perception

Another of the important monocular clues to distance is movement parallax, which is the apparent motion or change of relative location of objects caused by changing the point of view. This is indicated by the three pictures in Fig. 4. These pictures were taken from three points of view equidistant from the girl, and have correct perspective for normal reading distance. The top picture in Fig. 4 is the same as the central picture in Fig. 2. For the central picture, the camera was moved one foot to the right. The man, who is seen separate in the top picture, is partly hidden behind the girl's shoulder in the central picture.

Fig. 4. Photographs of same scene as in Fig. 2, with camera at slightly different locations, all 6 ft from girl, illustrating role of movement parallax in depth perception.

Fig. 5. Photographs of Fig. 2 at equal angular magnifications, all producing correct perspective, and illustrating role of forward-movement parallax in depth perception.

For the bottom picture, the camera was moved two more feet farther to the right. Now the man is behind the girl and is almost hidden. Neither subject had moved. The apparent motion caused by movement of the camera is movement parallax and is a very effective clue to distance and depth. The sense of depth is greatly enhanced when continuously changing parallax is produced, for instance, by moving a motion-picture camera sidewards, so as to show the scene from continuously changing points of view.

Parallax movements are also produced by moving the camera toward the scene, as illustrated by Fig. 5. In the bottom picture, taken with the camera 36 ft from the girl, the images of the subjects' heads are almost equal in size. In the central picture, taken with the camera 6 ft from the girl, the image of her head is more than twice as big as his. This change indicates, more clearly than either picture alone, the distance between the man and the girl.

False Perspectives Produced by Zoom Lenses

The enhancement of depth perception produced by movement of the camera toward the scene cannot be produced by the use of a zoom lens. The latter merely magnifies the image to variable extents without changing the point of view or introducing movement parallax. The difference is indicated by comparison of the set of pictures in Fig. 5, with the set shown in Fig. 6, in which the view from a fixed camera position is simply magnified.

Pictures taken with zoom lenses may give some sense of approach to the scene. But the sense of depth is merely that produced by the enlarged picture, and suffers from changing distortions as the picture is magnified up to and beyond the size for correct perspective.

The sense of depth produced by parallax, in motion pictures taken with moving cameras, is much greater than that produced by stationary cameras, whether or not zoom lenses are used.

If zoom lenses are used to make stereoscopic pictures, with the camera at an unchanging distance from the scene, then the false perspectives will be much more noticeable than when zoom lenses are used for nonstereoscopic pictures. When the magnification is increased, the farthest objects appear to approach much more quickly than the nearest objects, as illustrated by Fig. 6, and all objects and distances in the scene are compressed toward the observer. If the camera separation is increased when the magnification is increased, in an attempt to compensate for these compressions, then the farthest objects appear to grow bigger, and the nearest objects shrink in size as they approach. These effects are caused by false perspectives, and by unnatural binocular disparities, which overrule the natural presumption that the actual sizes of people do not depend upon their distance.

In stereoscopy, therefore, it is essential to move the camera toward the scene, instead of using zoom lenses, if the sense of approach is desired. Otherwise, the perception will be produced that the scene is being pushed and squashed toward the observer, with the foreground objects and actors shrinking in an unaccountable and perverse manner.

In viewing ordinary motion pictures, the absence of binocular clues does not reduce the effectiveness of monocular clues, which can give a very real sense of space and solidity.

Importance of Monocular Depth Clues in Stereoscopic Pictures

Monocular clues to distance do not lose their effectiveness when binocular clues are added. When monocular clues are consistent with the binocular disparities, they greatly reinforce the stereoscopic sense of depth.

However, if the binocular clues are inconsistent with the monocular clues,

Fig. 6. Bottom photograph of Fig. 2 at three different magnifications, yielding same-size images of girl as in Fig. 5, but false perspective in middle and top pictures. Variation of magnification of picture from fixed camera position (as with zoom lens) produces varying perspective distortions and does not produce perception of depth as effectively as forward movement of camera, as shown in Fig. 5.

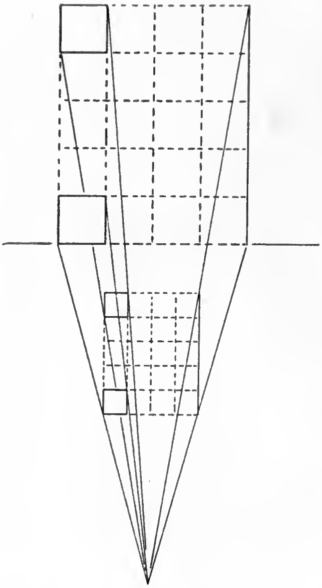

Fig. 7. Equivalence of perspectives of scenes, when sizes are proportional to distances. Objects of known size are naturally visualized at distances consistent with these sizes and with actual subtenses of images at the eyes of the observer. Screen-image of front object is assumed to be twice as large as known size of object.

a situation inevitable when telephoto, wide-angle or zoom lenses are used, the monocular clues are no less effective than the binocular disparities. Attempts are often made to conceal false perspective by separating stereo camera lenses by some distance different from the normal separation of human eyes. The result is a conflict between stereoscopic sensation and perspective. Such a conflict can be resolved only by perceiving distorted shapes, sizes and distances.

For example, if a stereoscopic head-on picture of a parade, taken with a camera a half mile away, is magnified so as to make the front rank of marchers appear within the theater, the more distant marchers will appear taller than the leaders and will seem to be marching down a hill, taking short steps and diminishing in height as they approach.

Use of camera separations greater than the normal separation between human eyes can make the distances between ranks appear greater. It can reduce the steepness of the hill, and lengthen the steps, but it will make the leaders look like dwarfs, or even like "paper dolls." This is due to the fact that, although the increased binocular disparities make the line seem longer and the leaders closer, the increased camera separation has not changed the angle that the leaders fill at the eyes of the audience. If a man, made to seem nearby, fills an angle not much greater than a man apparently three times as far away, then the closer man must be perceived as not much more than one-third as high as the more distant man. Also, since our two cooperating eyes cannot see appreciably farther around him than around the more distant man, the closer man appears paper-thin as well as unnaturally small.

Perspective is distorted to an exaggerated degree by telephoto cameras, but is also distorted by any camera used farther from or nearer to an object than the viewer imagines himself to be. In conventional motion-picture viewing, the principal actor is imagined to be at such a distance that he appears of normal size. If a viewer sitting 40 ft from a screen sees on it a 12-ft high image of an erect man, he naturally visualizes a normal-sized man about 20 ft in front of him. The ground plan corresponding to such visualization, corresponding to normal sizes, is indicated in Fig. 7. If the actual distance from the camera to the man was 20 ft, then all of his companions and surroundings near and far appear to be normal in size, distance, relative location and shape. If the camera was actually 300 ft from the man, then he will appear flat, as indicated by the ground plan of the visualized space in Fig. 8.

All of this can be seen even in non-stereoscopic motion pictures. But it isn't obtrusive.

Monocular clues play a powerful role in space perception. Their effects cannot be eliminated. If the monocular clues are distinctly inconsistent with the clues from binocular disparities, the scene appears unnatural and less acceptable than if the binocular disparities are simply omitted.

Binocular Depth Perception

Our two eyes view every scene from slightly different points of view approximately $2\frac{1}{2}$ in. apart, called the *interocular distance.* In this respect, our pair of eyes resemble a rangefinder. But here the resemblance ends.

A rangefinder determines the distance to an object essentially by measuring the angle between the rays coming to its two lenses, from a point on the object. Visual perception does not do this and does not necessarily locate an object at the geometric intersection of the rays reaching the two eyes from the object.

In ordinary experience, of course, that is usually where the object is, and that location is confirmed by monocular clues as well as by clues arising from other senses.

But visual perception is sufficiently adaptable so that if monocular clues, usually the angle filled by an object of known size, clearly suggest the distance of the object, that is where it will be seen. This will be so even if camera or projection conditions cause corresponding rays reaching the two eyes to come from a point at some quite different distance.

It is therefore a mistake to assume that visual perception is rigidly determined by ray directions and intersections. Our pair of eyes is not limited to working like a rangefinder.

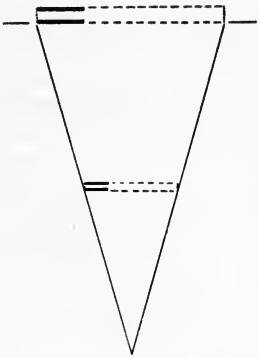

Fig. 8. Ground plans showing distortions of apparent depth induced by excessive magnification of perspective, for visualization at normal size and distance (between observer and screen) and at excessive size (behind screen).

A rangefinder with polarizers may be used in a theater to determine the location of the projected stereoscopic image of a man. But if the angular height of the image is that of a man 12 ft high at the measured distance, a viewer interested in the man and in the story he is acting will see him as a normal man at not more than half the measured distance.

False perspective may overrule the perception of a man of normal size, but binocular convergence alone cannot. Thus, if the man subtends a greater angle for the observer than he did at the camera, then the conflicting apparent heights of persons or familiar objects in the background may dominate the judgment of distance and make the actor in the foreground appear like a very close dwarf.

Such conflicts and distorted perceptions are especially likely to occur if the pictures are prepared with cameras separated by much more than the normal interocular distance. Use of camera separations less than the interocular distance is usually not troublesome. The result is intermediate between binocular and monocular perceptions, so that the conflicts are reduced. This is fortunate, because the normal linkage of accommodation with convergence makes unsatisfactory or even painful the viewing in large theaters of stereoscopic close-ups made with cameras separated as much as normal eyes. Therefore, it would be an exaggeration to assert that the use of camera separations different from $2\frac{1}{2}$ in. is never desirable. However, it is no exaggeration to point out that no choice of camera separation can eliminate false perspective, or correct the distortions caused by false perspective. On the other hand, if perspective is correct, then considerable variations of camera separations seem to be tolerable. The same cannot be said for considerable deviations from correct perspective, even when the camera separation is equal to the normal distance between the two eyes.

Stereopsis Rarely Sole Effective Clue

In binocular vision, the scenes from the two slightly different points of view are seen simultaneously and produce little or no consciousness of the difference of point of view. Consequently, the perception of space between objects seems so unique as to have a distinctive name "stereopsis" and to be described as "an entirely new sensation not even suggested in monocular vision."* However, the perception of absolute space is not determined by stereopsis.

It is often assumed that the perception of distance depends upon convergence of the eyes, through some mysterious contribution to sensation from the muscles that move the eyes. This is a fallacy,[4] equivalent to assuming that visual perception is as mechanical as a rangefinder. As Duke-Elder has written:

"Stereoscopy, depending on instantaneous parallax, is a relative measurement with reference to the fixation point. This, of course, leaves the fixation point itself undetermined. It was generally supposed that the localization of this point depended primarily upon the intersection of the fixation lines and the interpretation of the muscular sensations in the adjustment of the eyeballs and in accommodating for so doing. This is very questionable. It would seem that such localization is the result of a complex synthesis of all the various factors which, in addition to muscular adjustments, include the phenomenon of successive parallax and the interpretative faculties of experience."*

"It would seem that the essential point in the understanding of our powers of localization in space is the fact that factors of experience, such as aerial and geometric perspective, the overlapping of contours, the distribution of light and shade, our conceptions of size, and so on, combine with adjustment factors and physiological retinal processes in an extremely complex way to form a *unitary perceptual pattern which is appreciated and interpreted by consciousness as a whole.* Thus, uniocular localization, depending largely on extrinsic factors, appears in the final perceptual pattern to be of the same nature as binocular localization. The one replaces the other without apparent appreciation of change, and if unusual conditions are created so that the impressions of one conflict with the other, our spatial perception changes in a perfectly natural way in accordance with those sensory components which are for the moment the most potent. The unitary nature of the perception is nowhere better illustrated than in the fact that when the fixation point is changed and the gaze is directed from a near object to a distant one, even although the retinal disparity is altered we experience no fundamental impression of change, for the same object appears to be in the same place in the same unitary space."†

In his fascinating *Essay on Binocular Vision,* Lord Charnwood[5] has written:

"One of the most convincing demonstrations of the role that previous experience plays in vision is the stereoscopic range-

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* Reference 3, p. 133.

* Reference 2, p. 1080.

† Reference 2, p. 1081.

finder. In the eyepieces are a stereopair of graticules which are seen in relief in the plane of the image formed by the objectives, and in one telescope tube there is a variable prism system. Optically, the effect of operating the variable prism is to cause the distant scene to approach or recede; it cannot affect the image of the graticule, yet every observer sees the graticules move while the target stays put.

"If one trains one of these instruments on a distant hillside and operates its prism, so long as the indicated range is less than that to the solid hillside one can watch the graticule move to and fro across the intervening valley.

"It is clear from the above that convergence is playing no part in assisting the observer to tell whether the target or the graticule is the nearer, since the information that it can supply, namely, that it is the target and not the graticule that is moving, is completely ignored.

"The mind has no knowledge of the absolute value of the parallax angle of a given object, only of the difference between parallax angles.

"The mind can ignore stereopsis without suppressing the image of either eye, and will do so when stereopsis runs counter to its preconceived convictions.

"Stereopsis has no scale and is capable of many interpretations, the choice of interpretation being made in response to some outside factor. The most important of these is recollection of past experience, which is generally able to select the scale factor which makes possible a solution compatible with the subject's expectations. In the absence of any other determining factors, the mind's knowledge of the convergence of the eyes may supply a scale factor."

Perception of Normal Size Despite Binocular Clues

If one of a projected stereoscopic pair of pictures is moved sidewards during observation, a powerful perception of approach or recession of the entire scene is momentarily experienced. An excruciating pain may be felt if an excessive divergence is produced. But if the pair is left at a new and not painful separation, the scene will quite soon resume its formerly perceived location and dimensions.* During the movement, which of course does not change the visual angles subtended by the images of any of the objects, each object appears to undergo a rapid change of apparent size, proportional to its apparently changing distance. The size perceived at the end of the movement is so unnatural that the reinterpretation of the whole scene follows, more or less unconsciously and quickly, so as to restore the perception of the normal size, and consequently to re-establish the original perception of the distances.

This reinterpretation occurs most readily when the attention of the observer is concentrated on the scene and objects portrayed. It can be prevented if the attention is confined to the screen or its borders or to persons or objects in the theater. If this is done, the images can be localized more or less precisely with reference to the screen, regardless of anomalous perceptions of size. But this is not done by most viewers of stereoscopic pictures, who are interested in the story and prefer normal-sized actors.

The reinterpretation of an image geometrically twice normal size is indicated in Fig. 9. At the left is a map of the images as they would be

* A related phenomenon, even more strikingly indicative of the potentialities of perceptual adaptation, can be observed when one of a stereoscopic pair is rotated slightly in its own plane. If the left-eye image is rotated clockwise, all persons and objects in the picture will appear to fall forward, during the movement. But if the left image is allowed to remain at a position distinctly but not excessively rotated with respect to the right image, the scene quite soon resumes its former appearance, with all persons and objects erect. In this case, depending on the vertical levels of images on the retinas, visual perception is adapted to various degrees of retinal disparities for any one distance. In other words, the visual perception of the observer is simultaneously adapted, for different vertical levels of the retinas, to a considerable range of deviations from normal retinal disparities. Fundamental investigations of such phenomena are described and discussed in reference 3.

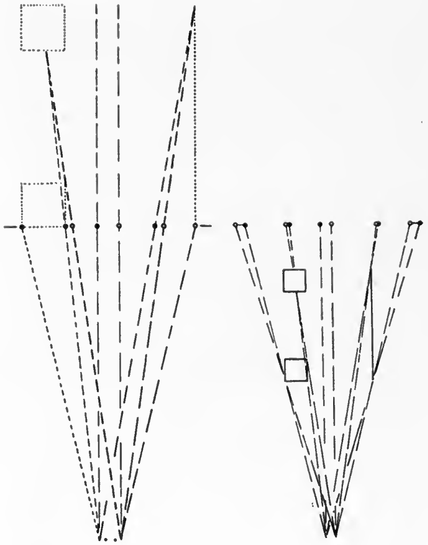

Fig. 9. Perceptual localization of objects of known sizes, at distances consistent with those sizes and the subtenses of the projected images, independent of binocular convergence. O: screen locations of selected details in right-eye image; ●: screen locations of same details in left-eye image. Left, images as projected and ground plan of perceived space if objects are not recognized; right, ground plan of perceived space for recognized objects of known size. Perception of distance is not determined by separation of corresponding images on screen, for objects of known size. Perception is the same whether images are separated as shown at right or at left.

located by use of a rangefinder having twice the normal interocular separation. The centers of the entrance apertures of the rangefinder are indicated by the intersections of the two pencils of rays. From these points of view the two views are in correct perspective. This assumes that the scene was photographed with cameras separated $2\frac{1}{2}$ in., at half the distance from the foremost object as the screen is from the observer.

Because of the magnification, the two images of any very distant point are separated on the screen by twice the normal interocular separation. However, as previously mentioned, so long as this separation is not excessive, and after adaptation to any change has occurred, the perception of distance in a scene does not depend upon the separation of the right and left images on the screen. That perception is of normal-sized objects, at whatever distance is consistent with their normal size and the angles their images are filling at the eyes of the observer. That is also where the stereoscopic images would be found by a rangefinder with normal interocular separation if the right and left images on the screen were moved closer together, as indicated on the right. Unlike the rangefinder, however, the human observer sees the images at their proper distance for normal size, regardless of separation of the images on the screen.

Stereoscopic Window

It is preferable to project the right and left images with separations as indicated on the left, and to let this property of visual perception (not shared by rangefinders) locate the objects properly. This is preferable because, with such separations, the edges of the screen also appear to come forward. Under these circumstances, the edges of the screen are perceived as a window through and behind which the scene is perceived.

If the images were projected as shown at the right, the edge of the screen would be perceived at the actual distance of the screen. The important foreground of the scene would be in front of the window, which would nevertheless destroy stereopsis at the sides of that region, in a very annoying and puzzling way.

Dependence of Perceived Distance on Monocular Clues

Perceived space is dependent primarily on monocular clues, most frequently the known normal size of familiar objects which are naturally visualized at such distances that they appear of normal size. Stereoscopic perception then spaces all other objects relative to that distance. This is the only, and quite subsidiary, role of stereopsis in the perception of distance. If the perspective in the picture is incorrect, that is, if the object on which the perception is based was not at a distance from the camera equal to the distance at which it is perceived, then stereopsis emphasizes the false perspective.

Effects of Camera Separations Greater Than Interocular

If the cameras are separated much more than the normal interocular distance, then binocular disparities can be experienced for objects much farther from the original scene than is normal for human vision. The natural and quite involuntary interpretation of such an experience is that the distances in the image are no greater than those for which stereopsis normally occurs. On the basis of this very effective clue, all distances in the scene are underestimated. Consequently, all objects in the scene are perceived proportionately closer than the original objects. Their shapes, however, are distorted and close objects appear smaller than identical objects at a distance.*

Objects photographed with telephoto lenses, and exhibited at greater visual angles than they subtended at the camera, appear too thin. This is called the "cardboard" effect and is a direct result of false perspective. Nothing can fully remedy this, except to reduce the magnification or to put the observer farther from the screen, so as to restore the angular subtenses of the original scene with respect to the camera. In most cases, the required distance from the screen exceeds that for which stereopsis is experienced, and the perception then does not differ in effect from conventional single-image projection.

The distortion of perspective produced by telephoto lenses cannot be remedied by increasing the interaxial separation of the cameras. That increase cannot correct the perspective in either of the images, but will only cause the clues of stereopsis to conflict with those of perspective and parallax. In such a case, stereopsis overrules the natural presumption that people and other familiar objects are the same size, whatever their distance. It may restore approximately the natural sense of depth, but it does so at the price of unnatural distortions of sizes and shapes of people and objects at different distances. The conflict between the monocular clues and binocular clues will make the more distant people appear to be taller and generally larger than those in front, as shown in Fig. 10. The ground plan of the space perceived in a very moderate case of double angular magnification

* The assertion is sometimes encountered, that use of a camera separation greater than normal interocular separation causes perception of a miniature model of the scene, reduced in all dimensions but otherwise undistorted. The following example illustrates the incorrectness of that conclusion. Two identical objects are in the scene, one 10% farther from the camera than the other. Therefore, regardless of focal length or camera separation, the image of the farther object is 91% as large as the image of the nearer object. If camera separation double the normal interocular is used, the farther object is made to appear 120% as far as the nearer object. The farther object must therefore appear to be $1.20 \times 0.91 = 1.09$, or 109% as large as the nearer object, that is, 9% larger. This is a moderate case. The enlargement of distant objects (or relative dwarfing of close objects) also distorts the shapes of objects that occupy much depth in the scene. Such enlargement of distant objects and/or dwarfing of close objects and distortions of all objects are inevitable consequences of use of camera separations greater than the normal interocular distance.

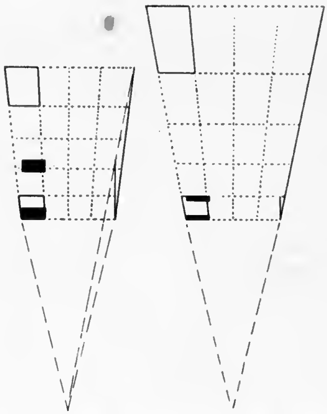

Fig. 10. False depth perceptions caused by excessive magnifications, and distortions caused by excessive interaxial separations. Natural presumption and perception of size constancy is overruled by binocular disparities inconsistent with perspectives. Left, double magnification with interaxial separations equal to and double observer's interocular; right, 5 times magnification with interaxial separations equal to and 5 times observer's interocular.

is shown by the solid black rectangles at the left, for normal camera separation. When the cameras are separated by double the normal interocular separation, the perception is as indicated by the enlarged, twisted quadrilaterals at the left. The ground plans of the spaces perceived with five times magnification and with normal and five times interocular separations are shown similarly at the right. Since giants are rarer than dwarfs, the judgments of absolute distance may be based on distant people and objects, taken to be normal. Then the people in the foreground appear to be closer and look like midgets.

Effects of Camera Separations Less Than Interocular

Objects photographed at very short distances and projected so as to subtend much smaller visual angles than they subtended at the camera will have exaggerated depth and may make excessive demands on the convergence and fusion capacity of the observer's vision.

Camera separations less than the normal interocular distance reduce those undesirable effects, but at the expense of conflicts of stereopsis and perspective. Stereopsis then overrules the natural perception of size constancy and produces distortions of the kind shown in Fig. 11. In this, the unbroken rays indicate the plan of the space perceived when pictures taken with normal interocular separations are viewed at the distance for normal perspective. The broken rays indicate the plan of the space perceived when pictures taken with one-half the normal interocular separation are viewed

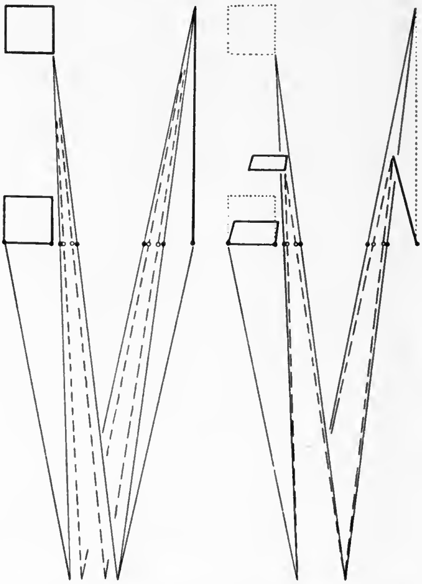

Fig. 11. Stereoscopic distortions caused by interaxial separation one-half of normal interocular. ●: screen images for interaxial separations equal to normal interocular are shown by solid circles; O: screen images for interaxial one-half of interocular. Left, ground plan of scene and cameras. Right, ground plan of perceived spaces.

at normal perspective and with normal interocular separation. The quadrilaterals drawn with unbroken lines at the right show the ground plan of the perceived space. In this case, the distortions arise entirely from stereopsis, and are caused entirely by the use of less than normal interocular separation. If a stereoscopic picture of a scene such as that at the top of Fig. 2 is made with a camera 2 ft from the subject, using a $\frac{1}{2}$-in. interaxial separation, and if it is projected at such a magnification that the face of a normal-sized girl is perceived 10 ft from the observer, the man will appear to be only 2 ft farther away in the background* and will appear to be only about 14 in. tall. This is because the man was actually 6 times as far from the camera as the girl, and his image on the film and on the screen is only one-sixth as large as hers. His distance is made to appear only 20% greater because of the small interaxial separation. The angle that the image of the man subtends at the eye of the observer corresponds, therefore, to a midget only one-fifth as high as a normal man, at the perceived distance of 12 ft. Many other details will be similarly distorted by the false perspective and by the less than normal interaxial separation, which breaks down the natural perception of size constancy.

These effects cannot be corrected by the reduced interaxial separation. This may overrule the presumption of size constancy, so as to make the depth appear nearly normal, but it does so at the expense of distorted perceptions of shape and size for objects at various distances. This is perhaps an extreme case, which could be avoided by elimination of persons or objects of recognizable size in the background. But such limitations of action and sets are not necessary for satisfactory results with conventional motion pictures.

* If the ratio of interaxial to interocular separation is i, and if the ratio of distances of the near and far objects is d, then the ratio of apparent distances of the near and far objects as perceived in the stereoscopic picture is $(1 - i + id)$.

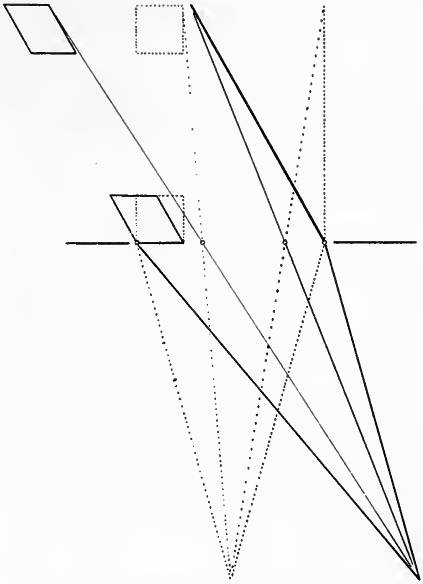

Fig. 12. Ground plans showing distortions of perceived space caused by false perspective arising from off-axis location of observer (solid lines). Dotted plan indicates space perceived by observer on axis and at distance for correct perspective.

Off-Axis Distortions

All the distortions and conflicts discussed so far have been those observed by the most favorably placed member of the audience. The only distortion that can be reduced by movement of the observer is that produced by telephoto stereographs made with camera interaxial separation equal to the observer's interocular separation. That distortion is reduced as the observer moves farther from the screen, but stereopsis usually becomes ineffective at the distance for which distortions of perspective are eliminated, even if the observer is not out of the theater before that distance is reached.

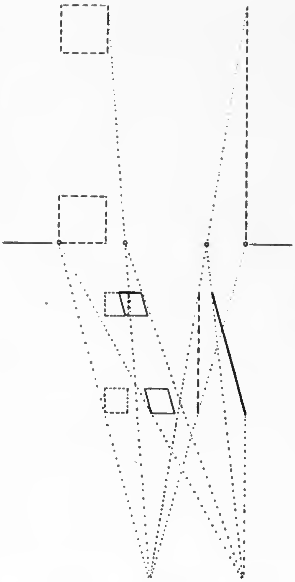

Fig. 13. Displacements of objects visualized at normal size and distance by off-axis observer. Screen-image of front object is assumed to be twice as large as known size of object. Ground plan of space perceived by on-axis observer is shown by broken lines, directly in front of screen. Displaced and distorted space perceived by off-axis observer is shown by unbroken lines, toward right.

All distortions of space perception experienced by observers far from the center of the theater when flat pictures are shown are also made much more noticeable by stereoscopy. The principal effect of off-axis location is indicated by the plan of the perceived space, as shown in Fig. 12, for the case of stereoscopic projection with perfect perspective and unit magnification of foreground objects. The images of all surfaces in the scene perpendicular to the optic axis of the camera are perceived as parallel to the screen. Lines parallel to the axis of the camera remain parallel to each other, but are oblique to the screen. The line corresponding to the optic axis of the camera is perceived by each observer as pointing directly at the center of his own head, no matter how he moves it. All angles are distorted to conform to the apparent obliquity of the center line. The case of double magnification is shown in Fig. 13, in which the objects are not only twisted but displaced by movement of the observer.

Lack of Parallax Movements in Stereoscopic Pictures

Unnatural perceptions result from stereoscopic pictures because parallax does not result from head movements. In normal experience, movement parallax is the source of one of the most important contributions to depth perception. Again quoting Duke-Elder,

"The effect of parallax is nowhere seen better than in a very thick wood: on standing still, one seems surrounded by a dense wall of foliage and undergrowth, but on walking quickly along, the impenetrability of the wall seems to vanish and we see far in among the trees, each one standing out with perfect stereoscopic precision. Similarly, when parallactic movements are accentuated, as when objects glide past us rapidly as we travel in a train, the illusion is created that they are nearer than they really are."*

When we move our head or our body, we see farther around real objects. We cannot do this with stereoscopic pictures. With them, head movements only give us the impression that all objects are twisting and moving so as to prevent our seeing behind them.

The lack of stereoscopic vision attributed to some people who have otherwise normal vision may be due to this fact. They may be more influenced by parallax movements in normal vision than they are by binocular disparities. For such persons, absence of parallax movements may be more of a loss than can be compensated for by the addition

* Reference 2, p. 1073.

of binocular disparities. For them, some conventional motion pictures made with moving cameras may give more satisfying impressions of depth than can stereoscopic motion pictures made from stationary points of view. The absence of parallax motions, which normally result from the observer's head movements, can be mitigated to a great extent by parallax movements of the camera. This seems to be more important in stereoscopic photography than in nonstereoscopic photography, because the enhanced sense of depth makes the absence of parallax movements much more noticeable.

This can, of course, be seen in ordinary motion pictures, since parallax movements depend essentially on monocular clues, but, like all distortions of perspective, their absence is made much more noticeable and objectionable by stereopsis.

Conclusion

Stereoscopy is a double-edged sword. Truly remarkable effects can be produced by it. Its entertainment value, for its own sake, is undeniable. Its value for educational and technical purposes is also unquestionable. However, stereoscopy reveals and accentuates all the distortions of perspective which are easily tolerated in conventional motion pictures, and which can be avoided in stereoscopy only by severe limitations on camera and projection practices.

Essentially, if distortions of perspective are to be avoided, the angle subtended by the image at the observer's eye must equal the angle subtended by the object at the camera.

Depth perception from binocular disparities will be consistent with normal perspective only if the camera interaxial separation is equal to the observer's interocular separation.

Normal interocular separation can produce stereoscopic perception only within the range of distance for stereopsis in normal vision. For greater distances, the binocular disparities are too small to be effective. Attempts to increase them by use of camera interaxial separations greater than the normal interocular distance will cause distorted perspective and false perceptions of distance, size and shape, especially for foreground objects.

For short object distances, camera separation as great as the normal interocular distance may cause excessive convergence and conflict of the normal linkage between convergence and focusing of the eye. Such effects may cause the breakdown of stereoscopic perception and may even cause discomfort. Attempts to remedy these troubles by reduction of camera interaxial separation cause distorted perspective and false perceptions of distance, size and shape, especially for background objects.

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Discussion

J. A. Maurer (J. A. Maurer, Inc.): One of the possible approaches to the problem of projecting and interpreting stereoscopic motion pictures is to assume that the eyes of each observer function together in the same manner as the two-lens systems of a rangefinder. On this basis, objects shown on the screen will appear to be located at the intersections of the lines of sight from the two eyes to their respective images on the screen. The consequences of this were worked out in detail in a paper by Raymond Spottiswoode which appeared in the *Journal* [in October 1952]. If this approach is right, we can see immediately that if an object in the picture is to be seen at infinity the two images of it on the screen must be $2\frac{1}{2}$ in. apart, this being the average separation of human eyes. Objects which are to be seen as located at the screen must, of course, be represented by two images which coincide on the screen, and this requirement determines the alignment of the two projectors. Now suppose we have films which satisfy both these conditions when projected on a screen 12 ft wide. If we project the same films to fill a screen 24 ft wide, the images of objects which should be seen at infinity will now be 5 in. apart instead of $2\frac{1}{2}$ in.; the lines of sight to them will diverge instead of being parallel, and these objects will appear, if such a thing is conceivable, to be farther away than infinity. If we were dealing with only one object we could correct this by realigning the projectors, but such a correction is impossible when we have many objects at different distances. The paper by Spottiswoode left me, at least, with the impression that this is a serious problem, and that it is necessary to design the 3-D picture to be projected on a screen of a specific size. Do you agree with this?

Dr. MacAdam: The adaptation capacity of the human visual system, including the brain, is such that you don't have to readjust the projectors, nor do you have to make the picture for specific screen size, so long as you avoid excessive divergence. This is an illustration of the fact that I have stated, that convergence does not determine the location of the object you see. The best adjustment of the camera, as Professor Rule and others have pointed out, is that which produces on the screen two almost coincident images of the foremost object (that is, the foremost object that stays in the picture a while, not one that gets thrown at you). When that is done, the edges of the screen appear like a window, behind which the bulk of the action takes place. If this is done, however, the separation of the two images of a very distant object may be rather great, maybe a foot or so, in a large theater. And yet the visual system, including the conscious and subconscious mind, makes the adjustment so that normal-size people are seen somewhere in the theater, usually not on the screen. If only the perspective is correct, all things appear where they were intended to appear, regardless of the size of the screen.

Max Glandbard (Filmwright Productions): I can recognize, as you say, and I accept it — that the mind can make all sorts of adaptations and can certainly handle a variation in divergence. That is, that although the $2\frac{1}{2}$-in. separation normally corresponds to an infinitely distant object, yet if the separation were greater than that, you would still accept it as infinity. On the other hand, I don't see it as a practical answer to the question that was posed, because of the other factor of how much strain are you inducing when you create that sort of situation. In other words, assuming that the mind would adapt so that the object was perceived at infinity, wouldn't the kind of situation in the example that was proposed cause serious eyestrain? How long could you view such a picture and keep making that adjustment without suffering a nervous collapse.

Dr. MacAdam: Stereoscopic rangefinder experience indicated, as I understand it, that divergence greater than half a degree would very soon become painful and very objectionable. I think that this might be taken as a guide for motion pictures also. That is, one should not allow more than one half a degree divergence. The mind will make adjustment so that the object causing greatest divergence appears to be at infinity, but anything beyond a half degree of divergence will induce excessive eyestrain. This means that folks in the front row may have a very painful experience, because they're sitting too close to the screen. For them a separation of images, which is a half degree for most of the audience, may be a whole degree.

Mr. Glandbard: From a practical viewpoint, if you did have the situation where a picture that was made for a 12-ft screen were to be projected on a 24-ft screen or the distance from the screen to the projector were changed, you then, to come back to the original question, would have to make some sort of an adjustment and adaptation for it, wouldn't you? That is from a practical viewpoint, if you were going to show a whole film.

Dr. MacAdam: Please set me straight. What is the practical situation? If you project on a larger screen in a larger theater, do you still keep the front row the same distance away from the screen? Or don't you make the front row a little bit further away from the screen?

Mr. Glandbard: No, the situation here is not a question of the front row, but the fact that if you shot a picture to be projected at a certain distance or certain magnification, as Spottiswoode refers to it, and at that specified distance or close to it you got a separation when you shot it originally of, let us say, $2\frac{1}{2}$ in. If your projection now is on a larger screen at a larger distance, you increased — you magnified — your distance of separation and you might have reached, as in the illustration proposed, 5 in. instead of $2\frac{1}{2}$. Now in a situation like that, it seems to me that you very definitely would have to do something about your projection conditions in that specific theater because the picture hadn't been shot for that specific theater. And, despite the fact that the brain can adapt and in a short period of time make it seem that it's all the same, from a practical consideration, it would have to very strongly enter into the picture.

Dr. MacAdam: The only trouble that I can see is that the eyes of some of the audience might have to diverge more than half a degree. The excess over the normal $2\frac{1}{2}$-in. interocular separation, in the case just cited, is $2\frac{1}{2}$ in. That extra $2\frac{1}{2}$-in. separation would cause a half a degree divergence for an observer sitting about 25 ft from the screen. That means that the closest observer should not sit closer than 25 ft. If you project on a still larger screen on which, for instance, the two images which were originally set up to be $2\frac{1}{2}$ inches apart are 10 in. apart, the excess separation which causes divergence is $7\frac{1}{2}$ in., and the closest member of your audience should not be closer than 75 ft. In general, the excess separation over $2\frac{1}{2}$ in., for an infinitely distant object, should not subtend more than half a degree for any of the audience whom you want to treat nicely.

Mr. Glandbard: Now, since we couldn't sort of discharge one-third of the theater capacity from the owner's viewpoint in order to accommodate this sort of thing, there is a practical answer in the sense that in a situation like that, where a picture has been shot for a certain specification, if you aimed the two projectors closer together and decreased the angle of divergence, you would correct to an appreciable extent the idea of going beyond infinity. What would happen, of course, is that the depth ranges would change somewhat.

Dr. MacAdam: When you increase the convergence of the projectors so as to bring the images of distant objects closer together, then you are increasing the convergence for near objects. The images of the principal actor will no longer be coincident on the screen, as Professor Rule and Mr. Spottiswoode and others have shown to be almost essential. In other words, the borders of the screen will no longer form a window behind which most of the action takes place. If you juggle with the projectors, to reduce divergence to a value tolerable to those sitting too close to the screen, a good bit of the action will take place forward of the screen border, forward of the window, and the whole audience will suffer.

A more important consideration is one which again affects most seriously the folks in the front row. If you point the projectors so as to bring the images of distant objects closer together, then the images of nearby objects are put farther apart, in the cross-eyed direction. Although, as I have said, convergence doesn't play a primary role in determining where the thing is perceived, it is an important factor for folks who are sitting close to the screen, because it has an influence where they focus their eyes. Severe eyestrain is caused by the resulting conflict between the accommodation-convergence relation and the actual distance of the screen, on which the eyes should be focused. Also, as I said previously, the stereoscopic window will not be where the maker of the film intended.

Richard H. Ranger (*Rangertone, Inc.*): I'd just like to make a comment. This field is, of course, quite foreign to what I'm engaged in, but I'm very interested in how many parallels there are between stereophonic work and stereopsis. In other words, it all boils down to the fact that you are trained from the time you're born to accept certain facts, and that the intention of making those facts real in your mind outweighs all these angles and factors. For example, in the stereophonic work, I think it was suggested briefly that if you see a person talking, on the right, and you hear him, you will say that that is the person on the right, even though the actual location of that sound may be 3 or 4 or 10 ft away. And once you've established that man's being on the right, and then somebody talks on the left, you feel perfectly at ease, although the two sound directions may be completely wrong. It seems to me that we've got a direct parallel between what you're talking about here in the adaptation of the human visual system to the inaccuracies of our work.

Robert V. Bernier (*Synthetic Vision Corporation*): You, I think, are implying that convergence has nothing whatsoever to do with the location of objects in space. And you are implying that in connection with the projection of pictures. Is that right?

Dr. MacAdam: Yes. But keep in mind that I am not implying that convergence has no effect on the observer. It can give him a lot of trouble, such as headaches from excessive convergence or divergence, and violation of the accommodation-convergence relation. But, as far as perception of where the thing is, in pictures of familiar things, monocular clues, such as image size, dominate, and convergence conveys no sense of absolute location.

Maj. Bernier: I feel that if perspective is eliminated from the scene that you are projecting on the screen, then convergence has a great deal to do with the location of that object in space. That can be tested, for example, by using two black cards with holes punched into them, with a certain disparity, displacement, between the holes, if you see what I mean.

Dr. MacAdam: I think so, and I agree that binocular disparities have a great deal to do with the perception of the relative locations of objects in space. But the geometrical intersection of rays does not determine the distance at which an object will be perceived. In ordinary life, of course, that is where it is, and that is where it is perceived to be. But in the viewing of stereoscopic photographs, it is rare, indeed, when an object is perceived at the distance corresponding to the virtual intersection of the corresponding rays reaching the eyes. If perspective is correct in the picture, the object is perceived at the distance the real object would have to be to fill the visual angle that it does in the picture. If perspective is not correct in the picture, distortions of size, shape and distance are perceived, and neither convergence nor disparities can be adjusted so as to eliminate them. The disparities between the scenes viewed by the two eyes do space things out and give this new sensation which has been called stereopsis, quite different from anything that perspective ever gave us. And, as I have mentioned, if you use increased camera separation, you can space out the marchers in a parade coming toward you, but the result will be to make the fellow in front look like a dwarf and the fellow at the tail end of the line will look like a giant.

Maj. Bernier: The point I was raising is simply that there are a number of factors, as you covered very well, that go together to help the brain determine where these objects are in space, and I feel that when perspective is apparent in the picture, it's there, that it is fighting with convergence. Therefore, the mind will not allow you to locate the true position of that object. You have a fight between the two. And I am saying that when perspective has been eliminated, then the mind has no trouble whatsoever utilizing convergence or the intersection of the two lines of sight to locate accurately that object in space. Do you agree?

Dr. MacAdam: I'm sorry. I can't. The most convergence can do is to locate things relative to each other. Equal convergence can make you aware that two things are at the same distance. Or convergence greater for one thing than another can make you aware that the first is closer. You can even estimate fairly accurately the ratio of their distances. But convergence alone cannot locate even approximately a lone object in otherwise empty space.

Comments Solicited by the Chairman of the Board of Editors

John A. Norling (*Loucks & Norling Studios*): I cannot agree that convergence alone does not serve to locate approximately a lone object in otherwise empty space. Convergence of the lines drawn from the centers of the stereo pair to a plane in front of the object will make the object seem to be far away. Convergence in the back of the object will make it seem to be close. I experimented with a baseball on a black background, hence there was no stereoscopic window to provide a clue as to the distance of observers from the screen.

In one experiment the ball was moved forward from well behind the point of convergence to well front of it. This experiment demonstrated clearly that an object in "otherwise empty space" was seen at locations whose distances could be judged approximately. Of course, correct, or nearly correct, perspective provided an important clue because of the increase in size as the ball approached.

In another experiment the ball was held at a fixed distance from the camera and stereo pairs were made with the picture axes converged from front to back of the object. Again there was a definite sense of movement of the ball from a distant plane to a closer one and a good approximation of distance could be made. Of course, true perspective was missing and the ball seemed to become smaller as it approached. But both experiments proved that lone objects can be located approximately and also that true perspective must be present in any 3-D scene. Perspective and convergence are partners all the way in stereoscopy.

Observer-from-screen distance and the place of the observer in the theater cannot be disregarded. If viewed from a sharp angle the 3-D picture will have what I call *inverted perspective*, a totally abnormal effect. The near edge of a cube will appear shorter than the farther edges. The farther off-center the observer is, the more marked the distortion, but mere movement of the head of a seated observer will not cause perverse twists of the scene. However, an observer far off-center will see fantastic and changing shape distortions in a rotating subject such as a merry-go-round.

As Dr. MacAdam has pointed out, long-focus lenses should not be used in 3-D cine photography. For 35mm film, I consider a 75mm lens as the upper limit and a 35mm as the lower limit and they should be used sparingly. My choice is 50mm for most scenes.

Convergence must be used so that a definite stereoscopic window can be established in front of the nearest object. It is difficult, if not impossible, to mask the screen accurately to form a window; it can best be done by masking on the film prints as Spottiswoode has proposed and used. If window masking is built into the prints, projectors can be toed in to reduce the separation of point-pairs at infinity, when projection is to be on a wide screen.

There has been much discussion about camera lens interaxial spacing and much confusion. Using a classic formula it can be shown that interaxial spacing would have to be reduced to as little as $\frac{1}{32}$ in. if the picture is planned for a 30-ft screen and contains close objects and those located at infinity. Doing this would produce a picture that would have no perceptible depth.

I have found from experience that Dr. MacAdam is right when he states that any great departure from interocular ($2\frac{1}{2}$ in.) in either direction will disturb the spatial arrangement of objects and introduce perspective distortions. I have found the limit of increase or decrease of the interaxial spacing should be held to about 40% and that these extremes should be used rarely and only in very special cases.

Comment by correspondence, from Dr. MacAdam: I suggest that Mr. Norling, or anyone who cares to repeat his first experiment, hang from a concealed support a faithful miniature replica of a baseball, either alone or near but not touching, overlapping or shadowing a regulation ball, against a black background. Then without telling anyone that the ball is a miniature, ask a few people to judge its distance. Some years ago, Professor Ames, at the Dartmouth Eye Institute, had an instructive series of demonstrations of this kind, all of which led to the conclusion that convergence alone was not a sufficient clue for distance perception, and that it was very easily overruled by other clues.

In Mr. Norling's second experiment, continuously changing convergence evoked the perception of forward movement, similar to the effects described on page 283 of this paper. If, however, stereoscopic pairs taken near the beginning and end of the sequence, or anywhere between, are viewed as still pictures, the ball will be perceived at the same distance in all, at which distance the ball seems to be of regulation size.

Continuous All-Electronic Scanner for 16mm Color Motion-Picture Film

By VICTOR GRAZIANO and KURT SCHLESINGER

The methods of converting the 24 frames/sec film standard to the 30 frames/sec television standard are discussed. The disadvantage of using storage-type devices is brought out in order to show the need for a flying-spot scanner in televising film in color. The reasons for choosing the jump-scan method in the Motorola scanner are given with emphasis on the advantage of the large optical aperture realized with this method. This is possible since no moving optical parts are needed between the tube and the film and the full opening of the lens can be used.

The various factors affecting registry both in time and space are enumerated. The solutions used to minimize the errors and the final results obtained are given. The use of a signal derived from the leading edges of the sprocket perforations to control the position of scan on the tube face to minimize bounce is described in detail. The use of this signal for continuous correction of film shrinkage is also shown. Other features of the scanner to be described are the anastigmatic deflection yoke and single-control adjustable gamma.

The advantages of nonstorage-type scanners for transparencies and film have come to be generally appreciated since the advent of color.[1] The use of the memory type of pickup tubes in connection with standard projectors has rendered satisfactory service for monochrome television; however, it was soon recognized that a film scanner for color could benefit from the use of the flying-spot technique. This approach offers the advantage of a definite and linear relationship between light and signal, and it is not afflicted by spurious signals and shading effects which may require manual adjustment.

A serious obstacle to the development of a nonstorage type of scanner under American standards is found in the non-integer relationship between television-field frequency (60 cycles/sec) and film-frame rate (24 cycles/sec). This complex ratio (5:2) rules out many of the solutions to the television-film problem which have been successfully practiced in Europe for many years.

One of the simplest approaches is the use of continuous film motion in connection with flying-spot scanning of equal amplitude and opposite direction. The

Presented on October 7, 1953, at the Society's Convention at New York by Victor Graziano (who read the paper) and Kurt Schlesinger, Motorola, Inc., 4545 Augusta Blvd., Chicago 51, Ill.
(This paper was first received October 1, 1953, and in revised form January 15, 1954.)

vertical sweep rate is the difference frequency (36 cycles/sec) between film-frame rate and field frequency (60 cycles/sec).[2] This simple system, while practical under European standards, is not applicable here, because it would show "picture joins" at certain retrace cycles.

The use of optical immobilizers of the continuous, shutter or prismatic type is perfectly feasible. This approach eases the tolerances for vertical scan to the same level as required now in television practice. The CBS color-film scanner[3] was probably the earliest American flying-spot scanner, using commercial 35mm film in connection with a Farnsworth dissector tube. Some years before, the Bell Laboratories under A. Jensen's direction had done pioneering work along similar lines[4] using specially adapted film reprints with 60 frames/sec.

The chief disadvantage of the early shutter systems was a serious loss of light, reducing the speed of the optics to *f*/8 and below.

Recent developments of new immobilizers using mirrors[5] or rotating prisms[6] constitute great progress, but their optical efficiency is bound to be lower than that of an all-electronic system, described herein, which needs no optical system between the camera lens and the scanning tube.

The Motorola all-electronic film scanner accomplishes registry of successive scans by the use of a complex vertical scanning motion. The kinescope performs a cycle of five complete picture scans, each lasting 1/60 sec, but none of them overlapping. Instead, a jump-scan component is added to the standard vertical sawtooth, the "jumps" being d-c levels judiciously controlled for each field period.

This method obviates the need for very high precision of the vertical sweep which is, in fact, no better than the standards of good engineering in modern television broadcasting. The tightest tolerances to be met are:

(a) linearity of optical coordination between tube face and film, including the classic problem of shrinkage correction; and

(b) nonuniformity of film motion.

This paper will report in more detail about our efforts to cope with these problems. It may be said, at this point, that it has been possible, by the application of inverse feedback and servo techniques between film and tube, to arrive at a solution which permits the transmission of 16mm film with a resolution matching the transmission capabilities of the standard 4-mc video channel.

Electronic Scanning

The relation between the various film-frame positions and the composite vertical scan on the flying-spot tube are shown in Fig. 1. The normal vertical sawtooth scan is shown foreshortened to 60% of the frame height to compensate for film motion. However, the method does not require a definite sawtooth amplitude and therefore any aspect ratio can be transmitted. Normally the sawtooth scan is reduced slightly from that shown to eliminate the appearance of the frame bar. The frame height given is the repetitive frame distance equivalent to the distance between leading edges of the sprocket holes. The jump scan provides the step needed to keep the sawtooth aligned with the frame being scanned. Its amplitude variations are restricted to the values given in Fig. 1 within a tolerance equivalent to one television line. In five successive television fields, two film frames have been scanned to complete the cycle. Therefore, the conversion of 24 film frames/sec to 60 television fields/sec is accomplished.

It can be seen that the problem of producing a satisfactory motion picture using the jump-scan method is primarily one of registering all five images, that is superimposing them to obtain a single image. The general registry problem

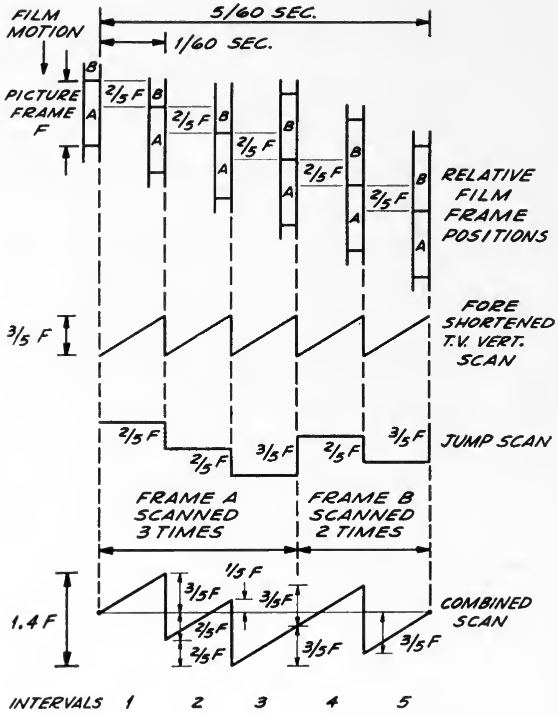


Fig. 1. Film and scan relations.

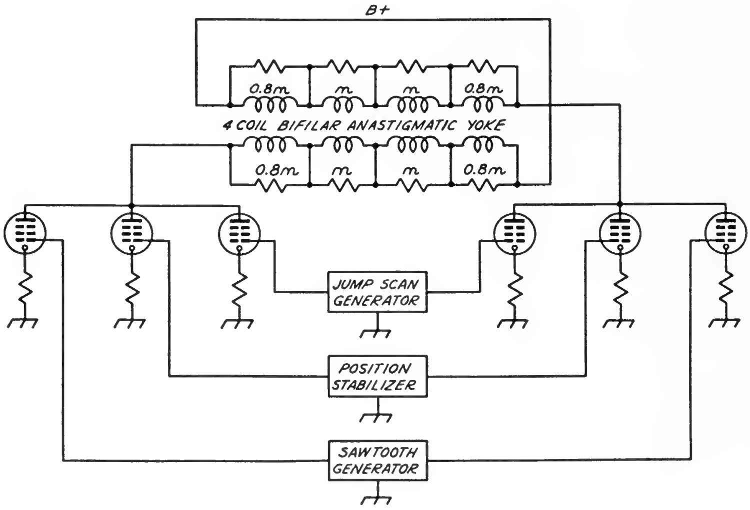


Fig. 2. Vertical deflection circuit.

can be divided into two classifications: one dealing with space registry, the other with time or motion registry. Since the five images occur not only in different positions but also at different times there is some interdependency between the time and space phases of the problem.

Registry in Space. It is only those errors which do not repeat for the five images which cause mis-registry. Nonlinearity in the sawtooth is a repetitive error and therefore does not show as a registry error. It is those factors which produce a nonlinear relation between the position of the image of the spot on the film plane and the current in the yoke, or to be more general, the grid-driving voltages to the sweep amplifiers, that are of importance. These factors can be put under the headings of yoke design and deflection, and of scanning-distortion correction. Other factors, such as lens distortions and film warpage, have proved negligible if good film-projector design practices are followed.

Yoke Design. Yoke distortions are difficult to analyze; however, considerable work has been done at Motorola by K. Schlesinger[7] and by A. Grimaila[8] on the influence of winding distribution on the value of the error coefficients. These results were utilized in designing the yoke used in the scanner.

The yoke windings are of the anastigmatic 4-coil semidistributed type as described by Schlesinger and utilizing the 0.8 astigmatism-correction factor of Grimaila (Fig. 2). Bifilar construction was used to provide for push-pull d-c operation. Resistances set for critical damping across each coil reduced the retrace transient to a negligible value. The driver tubes are 6AG7's with high cathode-degeneration factors. This fact combined with the relatively low inductance of the yoke provides for linear addition of the current components for sweep, jump scan and stabilization.

In order further to minimize the effects of yoke distortions the yoke inner diameter was made considerably larger than normal construction would dictate (Fig. 3). The inner diameter is 2 in. as compared to the tube neck diameter of $1\frac{7}{16}$ in.

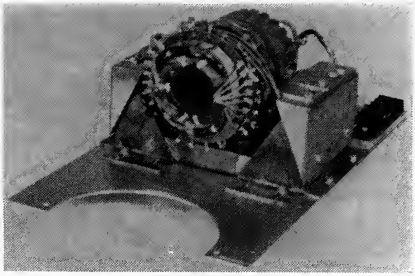


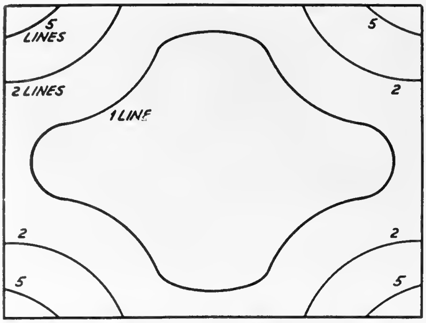
Fig. 3. Anastigmatic yoke.

Since both yoke and scanning errors increase rapidly with scanning angle, it is imperative to have the minimum angle consistent with satisfactory television performance. This is primarily dictated by spot size in available flying-spot tube types. The RCA experimental type #C-73236D used in this scanner is capable of 350 lines resolution when scanning a television raster of 1.8 in. horizontal width. This is equivalent to a 16° total scanning angle. The maximum vertical angle for jump-scan operation then becomes 17°.

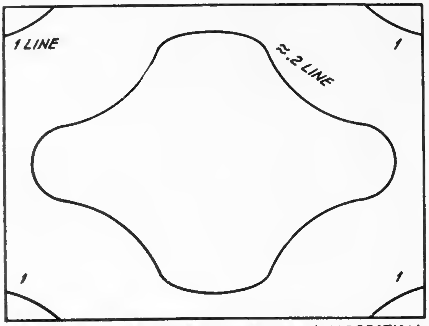
This proves to be a convenient raster size as a lens throw of 14 in. is obtained with standard 2-in. focal-length lenses.

Scanning Distortion Correction. Pincushion distortion due to magnetic scanning of a flat face tube is well known and is amenable to analysis.[9] It was found that under jump-scan conditions pincushion distortion accounted for by far the greater part of the registry errors once the large anastigmatic yoke was used. Without any form of correction the total error is in the order of five lines at the corners.

Correction for such scanning distortion by the use of external correcting fields has been described by Bull.[10] However,



CALCULATED ERROR DUE TO PINCUSHIONING OFF-REGISTRY
a



ERROR IMPROVEMENT DUE TO PINCUSHION CORRECTION
b

Fig. 4. Registry contours.

we have found that such correcting fields should be placed well into the drift space between yoke and screen in order to minimize defocusing effects.

In order to test the space registry independent of motion, a test was devised using a 30-cycle square wave superimposed upon the normal 60-cycle vertical scan. The amplitude of the square wave was adjusted so that center registry was obtained on the monitor image when a strip of film was placed in the gate. This, of course, results in scanning a wider angle (i.e. about 27° vs. 17° for jump-scan operation). However, the data so obtained can be interpreted in terms of the jump-scan problem with relative motion included, that is, with reference to the foreshortened vertical scan.

Figure 4A shows a contour chart of the flutter of a picture element as a function of position on the monitor image. These are calculated values assuming only pincushion distortion on a flat face. Measured results, from the square-wave test, using magneto-static pincushion-correction, are shown in Fig. 4B. These are values corrected for the case of jump-

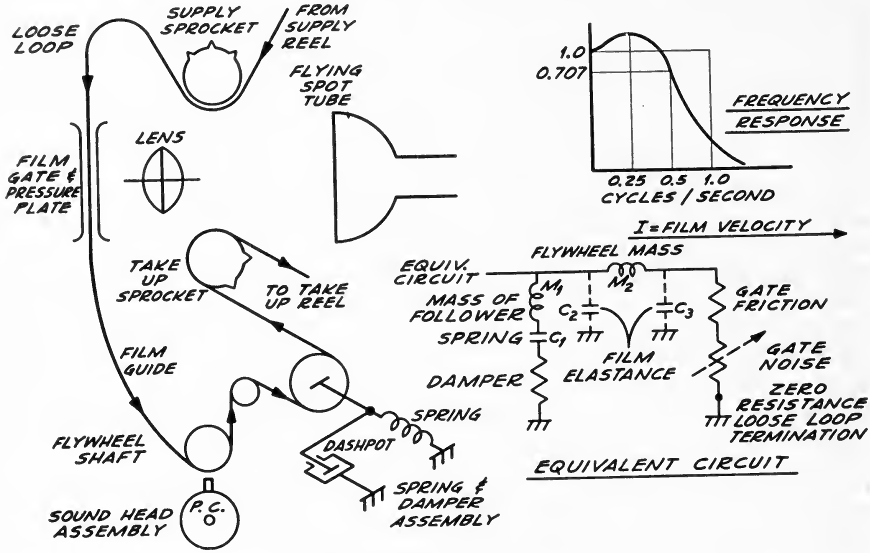


Fig. 5. Film-drive filter.

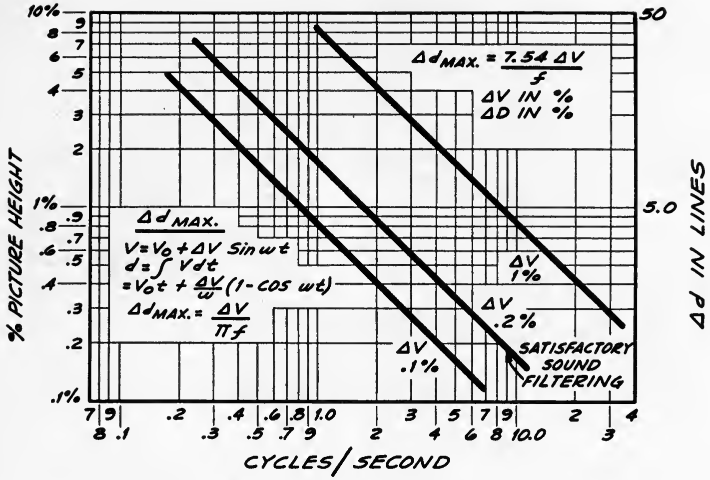


Fig. 6. Bounce amplitude vs. frequency.

scan operation. As shown, the corner flutter lies in the neighborhood of 1 line.

Registry in Time. The early objections to continuous-motion methods had been due to the inability of obtaining satisfactory uniformity of film motion within the gate. The British have been pioneers in this field as exemplified by the many excellent designs found in the literature.[11,12,13] They have been able to solve the problem by the judicious use of mechanical filtering. All of the designs described deal with 35mm film, where the sprocket-hole jitter occurs at 96 cycles/sec. When working with 16mm film, the same jitter frequency is as low as 24 cycles/sec. This requires a smoothing filter with four times the selectivity of the 35mm case. Our philosophy in this design has been to provide sufficient mechanical filtering to obtain satisfactory sound operation and then obtain picture stabilization by other means.

The mechanical filter and drive used in this scanner are shown in Fig. 5. A loose loop is used to isolate the supply-sprocket jitter from the gate. A straight gate with a pressure plate is used in this model; however, a semicircular system with a tensioning device can also be used. From the gate to the flywheel is a film guide in order to minimize the effects of film elastance C_3. The sound take-off is at the flywheel roller, the distance between gate center and the sound light beam being the standard 26 frames. Between the flywheel and the take-up sprocket is a spring-and-damper assembly to complete the filter. Since the jump-scan method requires the motor drive to be synchronized to the vertical synchronizing pulses, thyratrons operating as inverters are used. They are type 6012 running with a total input of approximately 30 w to drive a 1/75-hp synchronous motor.

The bandwidth of the system looking in from the take-up sprocket is 0.5 cycles/sec as shown. The value of the damping is slightly less than critical. Total velocity disturbances at the sound-head are in the vicinity of 0.1%. Somewhat higher figures are found at the gate due to the effects of gate noise and film elastance C_3. However, the disturbances are still within a 0.2% limit considered good for sound use.

Here it must be noted that solutions satisfactory for sound operation are not necessarily satisfactory for picture opera-

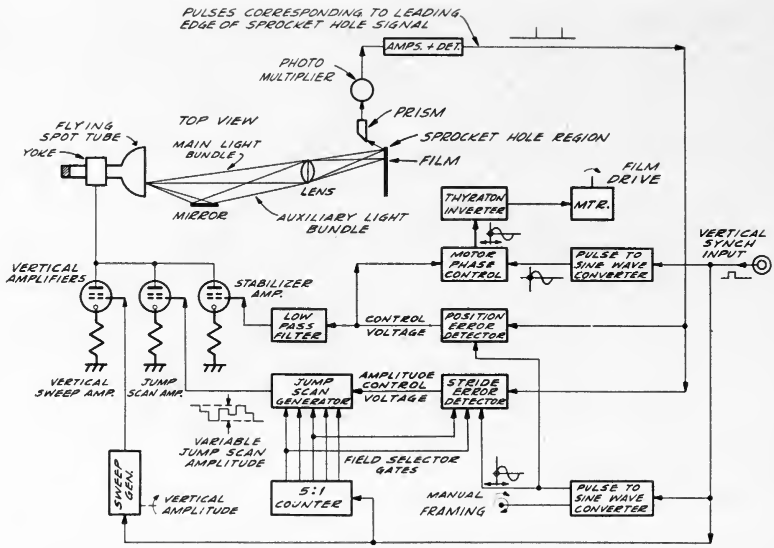


Fig. 7. Picture stabilizing system.

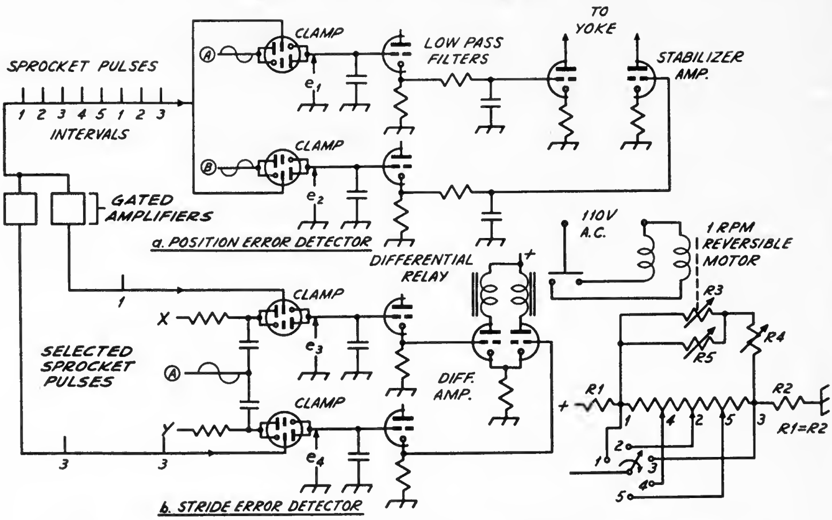


Fig. 8. Synchronous detectors for position and stride control.

tion as shown in Fig. 6. It is those velocity variations of 1 cycle/sec and below which are detrimental to picture quality. Hence, we are facing the problem of supplementing the mechanical filter by an electronic stabilizer.

Electronic Stabilization. The only position reference provided by the film is the sprocket hole. Frame-to-frame borders cannot be counted on to provide a reference.

The electronic stabilizing scheme used in the scanner is shown in blocks in Fig. 7. This stabilizer provides the following controls:

(a) Dynamic stabilization against slow vertical movements not filtered by mechanical drive.

(b) Centering of film frame with respect to television scan.

(c) Centering of scan on the flying-spot tube face in the vertical direction.

(d) Jump-scan, i.e. stride-amplitude correction to correct continuously for drift in amplifiers, in accelerating voltage of the flying-spot tube, and for shrinkage in film.

As shown in Fig. 7, mirror, lens and prism are used in such a way as to obtain a reflection signal from the film surface. The absence of such a signal signifies the presence of a sprocket hole. A pulse corresponding to the leading edge of the sprocket hole is derived and applied to the position-error detector and the stride-error detector. Both detectors are synchronous detectors which momentarily connect a comparison sine wave derived from vertical synchronizing signal to a storage condenser.

In the position detector, all sprocket-hole signals are used as shown in Fig. 8. Push-pull sine waves A and B are used to obtain push-pull correction voltages E_1 and E_2 which are applied after filtering to the stabilizing amplifiers. In this way, the stabilizing amplifiers follow any variation in film velocity with a corresponding change in scan position.

Certain limits of gain and frequency response are imposed by the intermittent nature of the information obtained by the position-error detector.[14] For example, with the 60-cycles/sec field rate and a loop gain of 10, a frequency response of 1.8 cycles/sec is the largest bandwidth that can be handled before instability occurs. Other conditions based on subjective reactions to vertical jitter seem to indicate that the filtering bandwidth should be of the order of one-third the critical value given by the instability criteria. The mechanical system bandwidth should be equal or below this value, for the same reasons. With a feedback gain of 13 as used in the scanner, the critical bandwidth is 1.5 cycles and the electrical filter bandwidth is 0.5 cycles which matches the mechanical filter. As a result, the electronic stabilizer corrects for bounce up to 0.5 cycles/sec while the mechanical system removes variations above that frequency.

The film shrinkage problem is well known. Offenhauser[15] quotes figures as large as 0.9%. In terms of the jump-scan problem this means maximum misregistry for the first and third images of 1.1% or 5.3 lines. High-voltage variations as well as drifts in amplifier gains, etc., will also affect this problem.

A 0.2% requirement in stride variation would require the following stabilities from the various factors involved:

Film shrinkage	±0.03%
High voltage	±0.06%
Gain stability	±0.03%

Gain stabilities for relatively long periods of the order required have been achieved through the use of stabilized power supplies and large degeneration factors within the amplifiers. However, in the case of high voltage, the problem has been more difficult. It is the high-voltage stabilization problem plus film shrinkage which makes automatic control of stride a necessity. Fortunately, in addition to position control, the sprocket-hole signal can also be used to obtain stride control.

Consider the case where shrinkage has occurred and the stride is larger than required. The position-error detector has adjusted the overall scan position so that interval two, the center interval (Fig. 1), is in the proper frame position. In such a case, the sprocket-hole signal for the first interval will occur later as the scan image is too far from the center of scan. In the same manner, the third image is too far from scan center, but in this case, the sprocket-hole signal occurs earlier than it does during the center interval. In producing the jump-scan wave a set of five taps on a low-impedance resistor string (Fig. 8B) provides the five voltages required. Therefore, strict proportionality between voltages is kept despite variations in total amplitude.

The second, fourth, and fifth interval signals are removed by gating and only the first and third are used to provide stride-error control as shown in Fig. 8B. Both clamps are connected to the sine wave A. The correcting voltages E_3 and E_4 are applied to a differential amplifier and relay combination. A difference between E_3 and E_4 above a threshold value will close the differential relay. The 1-rpm reversible motor will then adjust R_3 to bring the stride amplitude to a point in which the difference between E_3 and E_4 is again within the threshold. Push-pull d-c voltages are added at points X and Y to correct for slight registry errors occurring in the sprocket-hole signal, and for unbalance in the differential amplifier and relay.

If a position variation persists in one direction for an appreciable length of time, say $\frac{1}{2}$ sec, it will cause a false stride error. Through the use of the threshold available in the differential relay, and the slow-speed run, high-speed stop characteristics of the geared motor, it is possible to obtain control for stride errors better than 1 line without false control during position variations. By setting R_4 and R_5 to obtain control velocities of the order of 1 line/sec, it is possible to run the system at thresholds below 1 line without any detrimental effects to picture quality even during position variations.

The jump-scan generator uses gates generated in the 5:1 counter and a diode network. Its action is similar to a selector switch which for the duration of a field period is connected to any one of the points on the resistor string (Fig. 8B). During the vertical synchronizing pulse it jumps to the succeeding tap. In five fields it has completed the cycle and begins again at number one.

In order to correct for starting misphasing of the motor and for drifts in the equilibrium position of the spring-and-damper assembly it is necessary to use the position-control voltage for motor phasing. The motor-phasing unit (Fig. 7) effectively slows or speeds up the motor a small amount so that the scan is always returned to the center of the flying-spot tube face. It incorporates a threshold type of control so that the smaller bounce variations are ignored.

A variation of the phase of the sine wave, used for comparison in the detectors with respect to vertical synchronizing signal, is provided. This causes a change in the relation of film frame to television frame. It has been found necessary to provide such a control because of the variations of film frame to sprocket-hole relation found in various films.

The vertical synchronizing signal also provides the timing for the sawtooth generator and for the 5:1 counter which generates the gates for the jump-scan generator.

Gamma Control for Film

One of the special features of the Motorola development is a control unit for amplitude response which can be adjusted by the operator.

In the practice of NTSC color transmission, a gamma-correcting amplifier or rooter for each primary color is standard equipment. To prepare the signal for display in picture tubes with an average gamma constant of 2.2, a fixed transfer exponent of 0.46 is required for this rooter.[16] This figure assumes that the display device is the only cause for half-tone distortion. However, if color film is used as subject matter, it is found that additional gamma correction is required to cope with the nonlinearities of the photographic process. As pointed out in literature,[17,18] the half-tone rendition on film is in itself nonlinear and may add to the overall gamma of the system about as much distortion as the cathode-ray tube itself.

Accordingly, it is desirable to have, in each color channel, a gamma-control

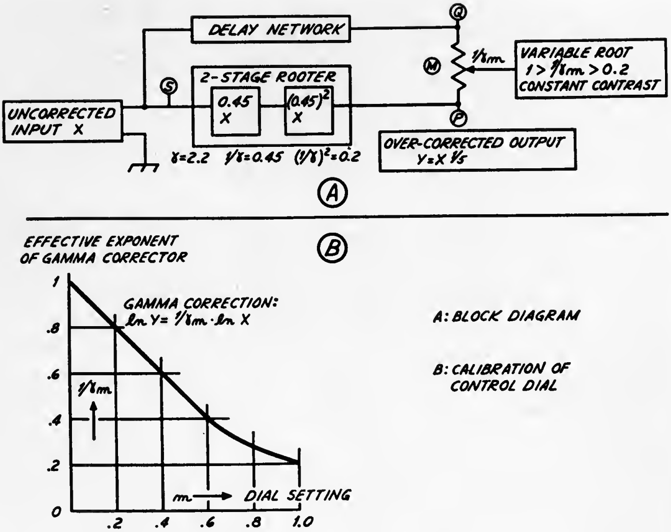


Fig. 9. Adjustable gamma control.

unit which has the general characteristic of a rooter:

$$\log(v_{out}) = 1/\gamma \cdot \log(v_{in}) \qquad (1)$$

where v_{in} = input signal voltage
v_{out} = output signal voltage
γ = gradient of characteristic to be corrected.

but permits to change the value of $1/\gamma$ between 0.2 and 1 without any change of contrast range.

Figure 9 shows a block diagram of the gamma-control unit used in our film scanner. It contains a rooter amplifier, which achieves the operation $y = x^{1/5}$ in two stages, each having an exponent of 1/2.2. The output from this rooter which has a loopgain of 1 and can correct for an overall gamma of 5, is available at terminal P.

A bypass is connected from the input S through a delay network to the point Q. A potentiometer between P and Q permits control of the shape of characteristic, available at the tap M, without a change in the black to white output level.

All transfer functions thus obtained may be expressed by:

$$y = m \cdot x^{0.2} + (1 - m) \cdot x \qquad (2)$$

where m is the calibration of the potentiometer, and y and x are normalized output and input, respectively. All curves go through end points $y = x = 1$ and $y = x = 0$.

Equation (2) is not a pure power law, except at the extreme positions $m = 0$ and $m = 1$. Nevertheless, any intermediate characteristic can be approximated by an equivalent power law, using the method of least squares. This has been done and the results are presented in Fig. 9B. The graph, computed for a voltage divider with linear taper, shows the effective power $1/\gamma$ of the rooter as a function of the setting m of the potentiometer. It is seen that the dial of this gamma-control unit presents a calibration of convenient linearity over most of the range.

General Description of Equipment

The 16mm scanner described in this paper and shown in operation September 28-30 for the National Electronics Conference at the Hotel Sherman in Chicago, is shown in Fig. 10. To the right is the

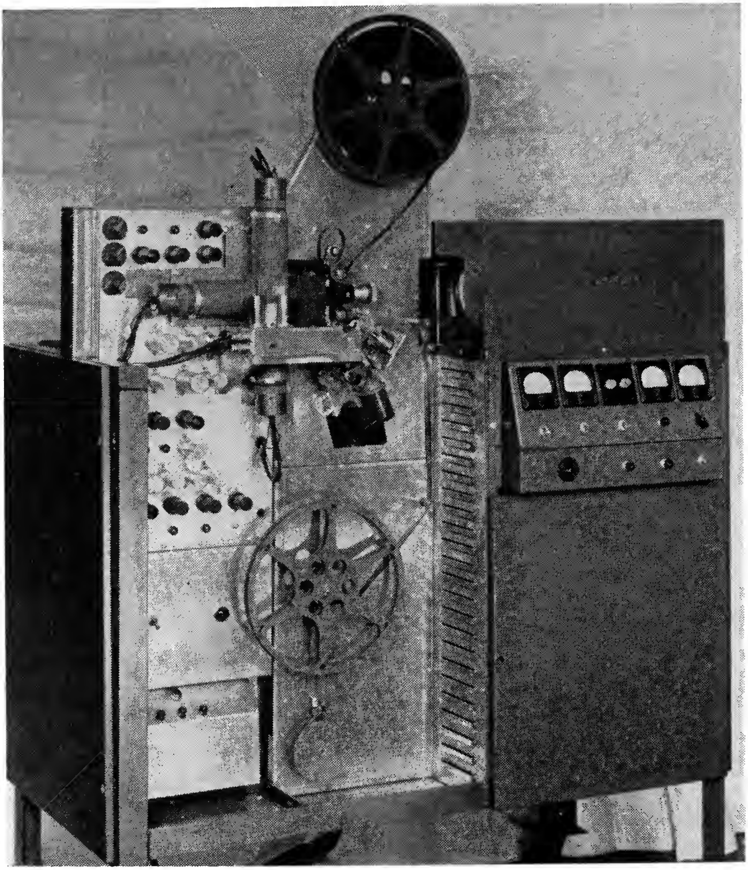


Fig. 10. All-electronic scanner.

flying-spot tube with the mirror which provides the second spot-light source used for the sprocket-hole signal. Below the tube are the control panel, high-voltage and sweep units. The control panel includes starting switches, a tri-color gain control, and monitoring meters for high voltage, cathode current of flying-spot tube, and video output. To the left can be seen the lens mounting with supply and take-up sprockets. The supply reel is above while the take-up reel is shown below.

The film path, from the supply sprocket, includes a loose loop before entry into the straight gate. The large T-shaped enclosure behind the gate holds the dichroic filters with red, green and blue photomultipliers which drive the preamplifiers shown. Phosphor decay correction controls as well as individual color gains for white balancing are provided.

The curved prism and light pipe assembly used for obtaining the reflected sprocket-hole signal is placed on the outside of the gate. The sprocket-hole photomultiplier with amplifiers and detector is mounted on the subchassis shown in front of the dichroic system.

Below the gate can be seen the film guide followed by the flywheel roller and oundhead. The spring-and-damper ssembly between the soundhead and he take-up sprocket completes the nechanical filter assembly.

Thyratron inverters within the unit provide the synchronous power for the notor driving the sprockets.

Acknowledgment

The authors wish to thank Prof. D. E. Noble, Director of Research, for his continued interest and encouragement during the extended course of this project.

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Networks for Theater Television

By FRANK A. COWAN

It is anticipated that theater television will require networks of intercity and local video distribution channels similar to those now furnished for television broadcasting. To meet needs of broadcasters and occasional theater requirements, the network circuits are being rapidly extended. Currently about 40,000 miles of video circuits are in use for television network facilities. Both radio relay and coaxial systems are used in these networks. Many special designs and operating features are required to insure good transmission over the long distances involved in nationwide network service.

Existing Television Networks

If theater television is to have simultaneous presentation at theaters in various parts of the country as well as spontaneity it will require networks similar to those now furnished for television broadcasting.

The Bell System now supplies television channels for use of all the major television broadcasters. It also supplies facilities for occasional theater television shows and for other "closed circuit" transmissions.

Intercity transmission of television signals on a regular commercial basis was started on May 1, 1948, and has grown rapidly since that time. At the start, the channels available for service totaled 900 miles — one channel in each direction between New York and Washington, and one in each direction between New York and Boston. The networks now span the United States and extend into Canada. At present there is a total of about 40,000 channel miles of intercity video facilities; about 25,000 channel miles of these are on radio relay facilities and 15,000 channel miles on coaxial cable. In addition to these intercity mileages, the Bell System also supplies many miles of local channels in the various cities of the nation. These provide connections between the terminals of the intercity networks and the broadcasting studios, and between studios and transmitters. Audio channels are also provided paralleling the video facilities. Figure 1 shows the layout of existing and planned television network routes. At the moment of this writing these networks are serving 204 stations in 130 cities.

Types of Facilities

Television requires transmission of a wide band of frequencies. For intercity transmission, two types of transmission facilities are available — coaxial cable and radio relay. A channel of either type is capable of carrying hundreds of message

Presented on Oct. 7, 1953, at the Society's Convention at New York by Frank A. Cowan, Long Lines Dept., American Telephone and Telegraph Co., 32 Ave. of Americas, New York 13. (This paper was received Jan. 25, 1954.)

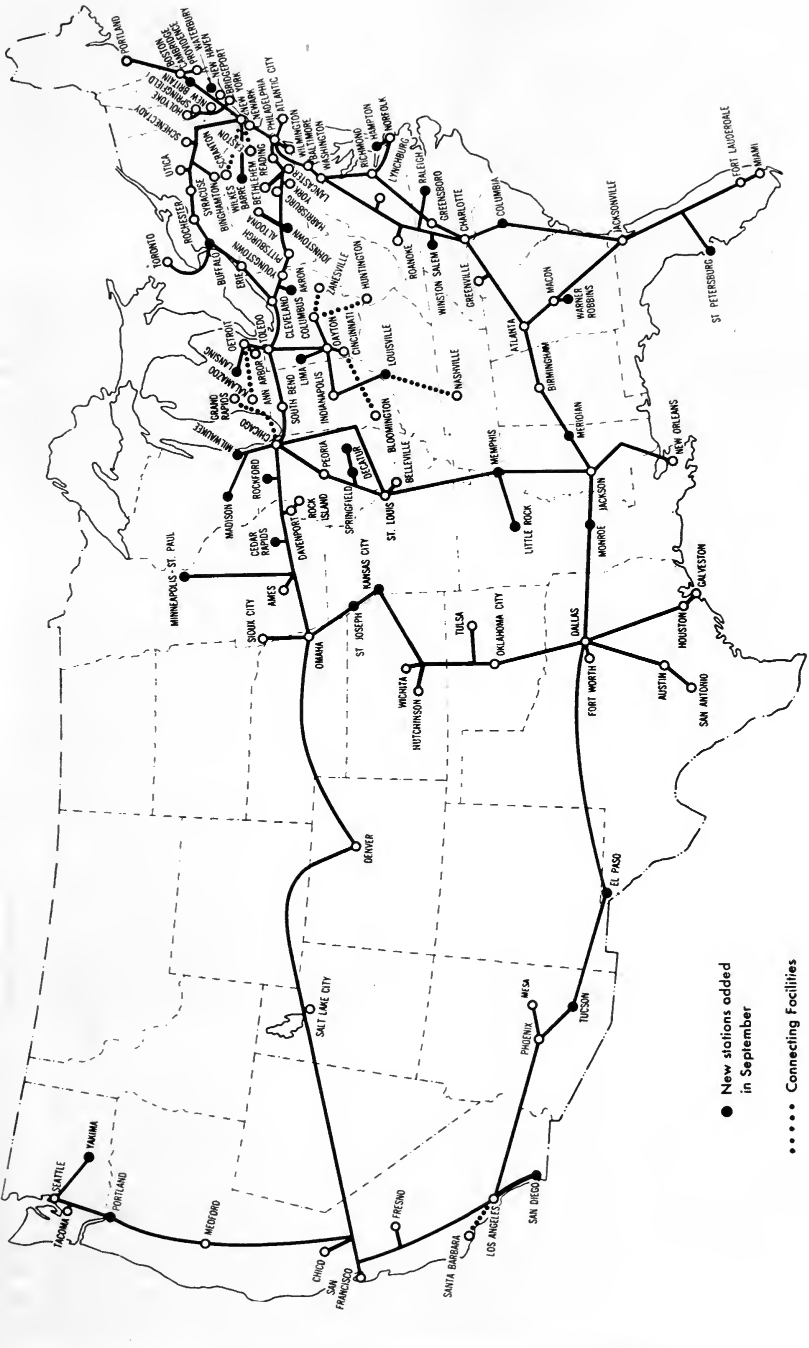


Fig. 1. Bell System intercity television routes, Sept. 1953.

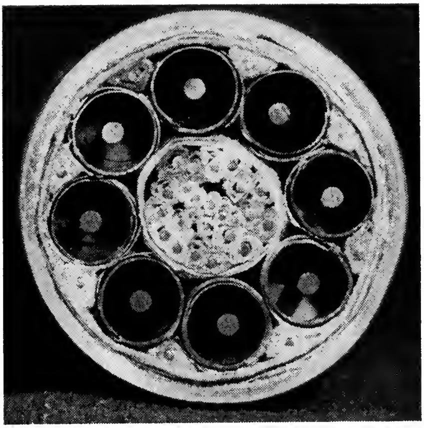


Fig. 2. Cross section of a coaxial cable.

telephone circuits or one television program.

Coaxial Cable. A coaxial conductor consists of a copper tube at the center of which is suspended a copper wire. The structure is such that the electromagnetic field is largely confined within the tube and there is little susceptibility to outside interference at frequencies above about 50 kc. The usual size of tube is $\frac{3}{8}$ in. in diameter. Generally, eight coaxials are contained in each cable sheath, four transmitting in one direction and four in the other. Figure 2 shows a cross section of a coaxial cable.

Fig. 3. Coaxial cable auxiliary repeater station.

Amplification must be provided at frequent intervals to offset losses of the cable. Two types of coaxial cable system are in use in the Bell System today. One, known as L1, has amplifiers spaced approximately 8 miles apart and passes frequencies up to about 3.1 mc. The second, and newer system, known as L3, requires amplifiers every 4 miles and

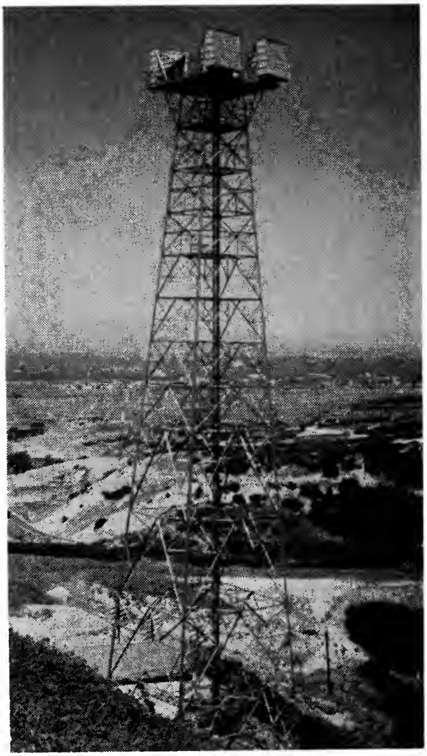


Fig. 4. TD-2 radio relay station.

passes frequencies up to about 8 mc. Figure 3 is a view of a typical coaxial repeater station.

Both coaxial systems utilize carrier techniques to transmit video signals, since the very low frequencies of the video band are not transmitted over coaxial cables. The carrier frequencies

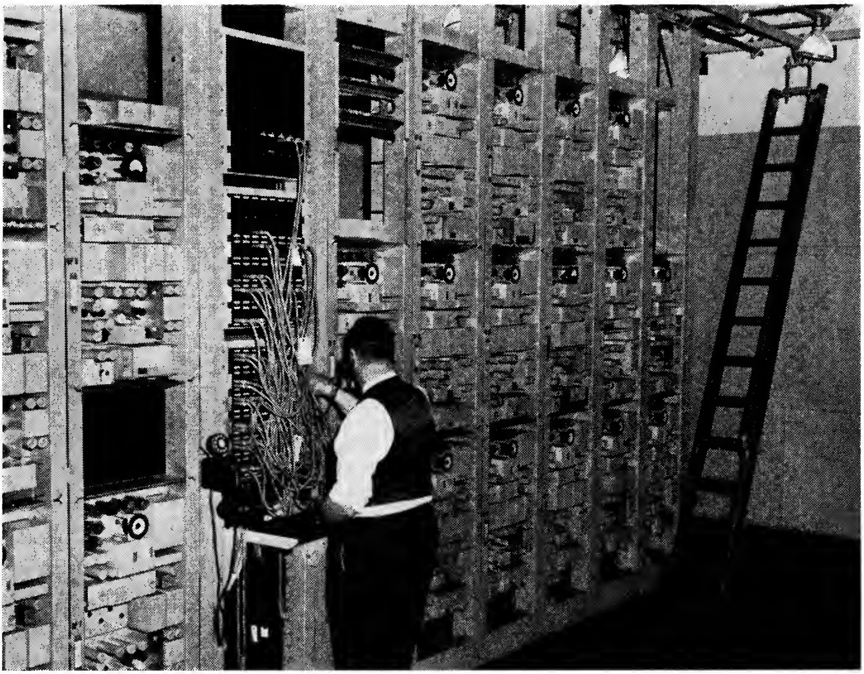


Fig. 5. Video amplifiers in telephone central office.

Fig. 6. Local channel microwave equipment on Empire State Building.

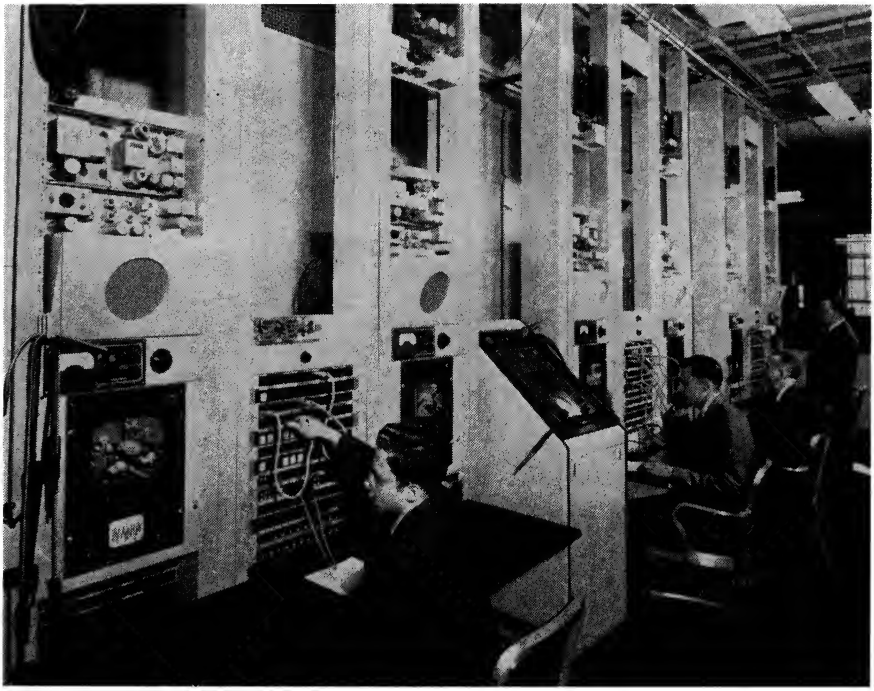


Fig. 7. New York intercity television operating center.

are 311 kc for the L1 system, and 4.139 mc for the L3 system. (In the latter system, 600 message circuits are carried on the same coaxial in the frequency space below 3 mc.) Both systems employ vestigial sideband transmission, transmitting only a vestige of the lower sideband.

Radio Relay. The radio relay system principally used for television is designated TD-2. This is a microwave system operating in the frequency range of 3700–4200 mc. A single system is capable of providing six channels in each direction. To guard against interruption, one channel is usually assigned to be a protection standby and is switched in to replace any of the working channels on which trouble is experienced. Amplifier relay stations are required at distances of approximately 25 to 30 miles along radio relay routes. Figure 4 is a view of a typical radio relay station.

Local Channels

Local channels may consist of either cable or microwave radio facilities.

The cable facilities generally consist of special shielded pairs with amplifiers spaced 3 to 4 miles apart. Transmission is at video frequencies. The balanced construction of the pairs helps prevent low-frequency interference and noise which would be present if coaxial construction were used. An installation of video amplifiers in a telephone central office is shown in Fig. 5.

The microwave facilities used in some cases are generally single-channel systems. Figure 6 shows two microwave equipments on top of the Empire State Building which are used to provide local channels in and around New York.

Operating Centers

To enable coordinated operation of network television transmissions, operat-

Fig. 8. Intercity video pushbutton switching panels.

ing centers are provided at network terminals and at junction points along the network routes. At these centers monitoring equipment is provided to enable the quality of the picture to be observed, and any troubles in transmission to be detected and the cause located. Figure 7 is a view of the operating center at New York.

The operating centers also provide switches of the various network sections and of the local channels in accordance with the customer's operating requirements. For example, a given station may take programs from several networks, requiring switches to be made at intervals during the course of each day; or a given network may require switches to enable the programs to be originated in turn from New York, Los Angeles and Washington. To enable rapid and accurate switching at operating centers, all incoming circuits and all outgoing circuits are connected to a pushbutton switching panel which enables any outgoing circuit to be fed from any incoming circuit. Figure 8 shows a switching panel capable of handling 20 incoming and 24 outgoing channels.

When network sections are switched, the operation is usually performed by switching relays operating at line frequencies rather than at video frequencies to avoid the accumulation of small distortions which would occur if the signals were demodulated to video and then modulated back to line frequencies at each switching point. Such switching is

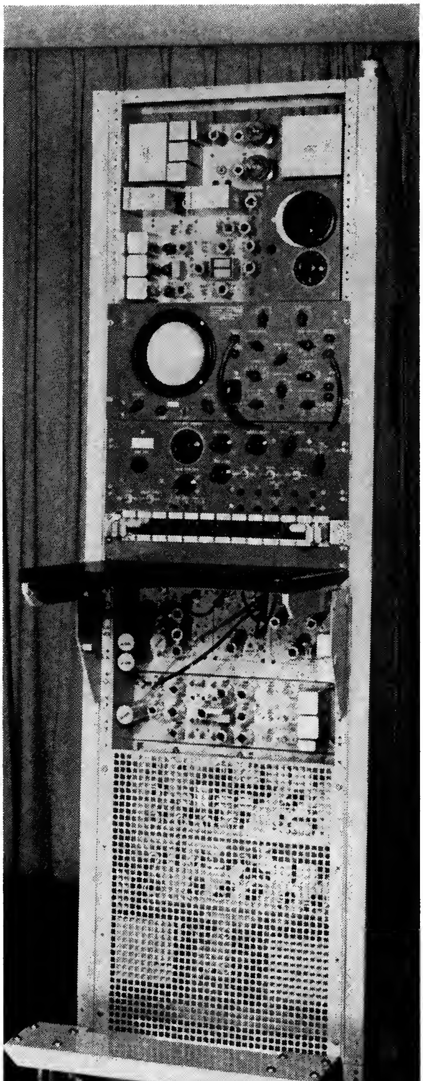


Fig. 9. Visual gain and delay measuring set.

accomplished by means of remotely controlled switches under control of the operating center.

Maintenance

Television circuits must be kept within very stringent limitations with regard to both amplitude-frequency and delay-frequency response. This is done by a regular maintenance program, using special testing equipment by which both individual sections and entire networks are measured, and necessary adjustments made to provide satisfactory transmission.

As an illustration of such test equipment, Fig. 9 shows a visual gain and delay set which provides an oscilloscope presentation of both amplitude and delay responses.

Wider Band for Theaters

Theater television transmissions to date have been in monochrome and have utilized the same types of facilities as provided for television broadcasters. In the future, theater shows may swing to color. The color system adopted may be a system such as the National Television System Committee color system, but it may be of the sequential type.

If greater band widths are required, the Bell System will be in a position to supply them. Both the TD-2 radio relay system and the L3 coaxial cable system are fundamentally capable of carrying a bandwidth of at least 8 mc. Figures 10 and 11 show measured responses, respectively, of a representative TD-2 radio relay channel and of a representative L3 coaxial channel. Future systems, one of which is already in the planning stage, will be capable of still greater bandwidths. With reasonable advance notice of requirements, we expect to be able to meet theater television's needs for both quantities of circuits and quality of transmission.

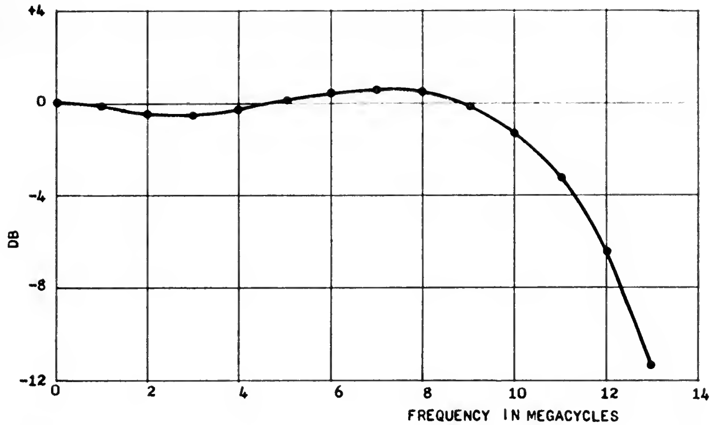


Fig. 10. TD-2 radio relay transmission frequency characteristic.

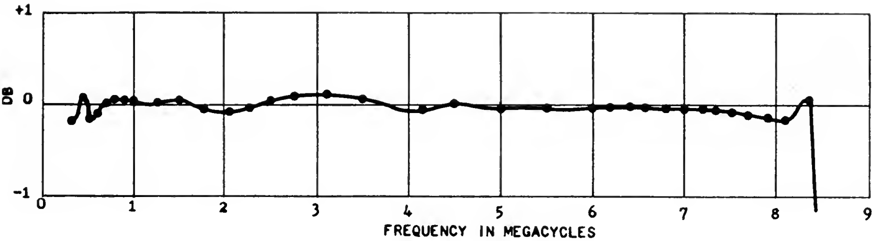


Fig. 11. L3 coaxial carrier transmission frequency characteristic.

Treasurer's Report — January 1 — December 31, 1953

CASH				
Cash on Deposit—Regular Account—January 1, 1953			$13,644	
Cash Receipts		$269,799		
Cash Disbursements—Operations	$264,152			
To Close Account	19,290	283,443		
Net Cash			(13,644)	
Cash on Deposit—Regular Account—December 31, 1953				$ —0—
Cash on Deposit—Payroll Account—January 1, 1953		$ 559		
Deposits		60,000		
Total			$60,559	
Disbursements—Payroll through November 15, 1953		$ 55,160		
To Close Account		5,499	60,559	
Cash on Deposit—Payroll Account—December 31, 1953				$ —0—
Receipts and Deposits to General Account			$61,075	
Disbursements		$ 30,180		
To Establish Office Account		20,000	50,180	
Cash on Deposit—General Account—December 31, 1953				$10,895
Deposits to Office Account—Transfers from General Account			$49,997	
Disbursements			29,997	
Cash on Deposit—Office Account				$20,000
Petty Cash Fund				200
Cash on Deposit and on Hand				$31,095
INVESTMENTS				
Savings Accounts—January 1, 1953		$ 5,795		
Add: Interest Credited @ 3½%		204		
Savings Accounts—December 31, 1953			$ 5,999	
U.S. Gov't. Bonds(at cost) January 1, 1953		$ 60,000		
Less: Bonds Matured and Redeemed		10,000		
U.S. Gov't. Bonds (at cost) December 31, 1953			$50,000	
Total Investments				$55,999
Total Cash & Investments—December 31, 1953				$87,094

Respectfully submitted,
BARTON KREUZER, Treasurer

Summary of Financial Condition — Dec. 31, 1953

ASSETS	
Cash in Bank—General Account	$ 10,895
Cash in Bank—Office Account	20,000
Petty Cash Fund	200
Savings Accounts	5,999
U. S. Government Bonds (at cost)	50,000
Accounts Receivable	42,131
Test Film Inventory	7,608
Test Film Equipment (memo value)	1
Office Furniture & Equipment (memo value)	1
Prepaid Expenses	1,860
Total Assets	$138,695
LIABILITIES AND RETAINED INCOME	
Accounts Payable	$ 12,311
Customers' Advance Payments	1,112
Membership Dues Received in Advance	19,511
Withholding Taxes Payable	2,888
N.Y.C. Sales Tax Payable	96
FOAB Payable	241
Federal Excise Tax Payable	24
Reserve for Replacement of Test Film Equipment	15,070
Reserve for 1955 Five Year Index	1,500
Total Liabilities	$ 52,753
Income Retained for Working Capital and Contingencies	85,942
Total Liabilities and Retained Income	$138,695

Statement of Income and Expenses

January 1—December 31, 1953

Test Film Operations		
Test Film Sales	$191,089	
Cost of Test Films Sold	129,741	
Net Income From Test Film Operations		$61,348
Membership Operations		
Total Membership Dues Income	$ 75,647	
Total Cost of Membership Operations	13,296	
Net Income From Membership Operations		62,351
Publications Operations		
Total Income from Publications	$ 22,229	
Total Cost of Publications Operations	69,254	
Net Loss From Publications Operations		(47,025)
Conventions Operations		
Total Income From Conventions	$ 20,839	
Total Cost of Conventions Operations	25,668	
Net loss From Conventions Operations		(4,829)
Other Sales Operations		
Total Other Sales	$ 1,118	
Total Cost of Other Sales Operations	1,345	
Net Loss From Other Sales Operations		(227)
Total Operating Income		$71,618
Operating Expenses		
Engineering	$ 13,696	
Nonengineering Committees	597	
Administrative	72,947	
Officers	170	
Sections and Chapters	4,550	
Affiliations	1,400	
Total Operating Expenses		93,360
Net Operating Income		($21,742)
Other Income		1,674
		($20,068)
Other Deductions		
Provision for Replacement of Test Film Equipment	$ 8,000	
Provision for 1955 Five-Year Index	500	
Total Other Deductions		8,500
Excess of Expenses Over Income		($28,568)

The foregoing financial statements were prepared from the records of the Society for the year 1953 and reflect the results of operations for that year. The records and financial statements were audited for the year ended December 31, 1953, by Smith and Flanagan, Certified Public Accountants, New York City, and are in conformity with that audit.

FRANK E. CAHILL, JR., *Financial Vice-President*

Membership Report, for Year Ended December 31, 1953

	Hon.	Fel.	Act.	Assoc.	Stud.	Total Indiv.	Sust.	Total Memb.
Membership, January 1, 1953	3	219	1266	1963	204	3655	81	3736
New Members			366	543	98	1007	8	1015
Reinstatements			18	30	6	54	1	55
	3	219	1650	2536	308	4716	90	4806
Resignations		−6	−21	−33	−5	−65		−65
Deceased		−1	−12	−10		−23		−23
Delinquents		−3	−66	−161	−49	−279	−8	−287
	3	209	1551	2332	254	4349	82	4431
Transfers:								
Active to Fellow		14	−14					
Associate to Active			41	−41				
Student to Associate				36	−36			
Active to Associate			−3	3				
Membership, December 31, 1953	3	223	1575	2330	218	4349	82	4431

Nonmember Subscription Report for 1953

Subscriptions, January 1, 1953	1218
New Subscriptions and Previous Cutoffs	242
	1460
Cutoffs and Expirations	350
Subscriptions, December 31, 1953	1110

New Prices

Price Increase: Single copies of the *Journal* will cost more beginning May 1. The new price is $2.00 for each individual copy of the *Journal* and of the earlier transactions, except those three recent *Journals* that include special Part II's, the issues of last April, August and September (published with a Part II on magnetic sound, screen brightness, stereophonic sound), which will be $2.50. Members, however, receive a 10% discount. Postage for all publications will continue to be prepaid by the Society.

Handling Charge: It has become necessary to apply a 10% service charge to cover the Society's costs of handling all test films produced by the Motion Picture Research Council. On May 1 and after, this added charge will appear on all test film invoices that include MPRC films.

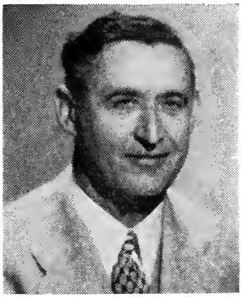
Awards

The complete 1953 awards story appears in the December 1953 *Journal*, and the full listings for all the previous years are shown in the April 1953 *Journal*. In the interests of economy the annual story covering each award cumulatively since its inception is omitted from this year's April *Journal*. The listing of Honorary Members and the Society's Honor Roll appear in the Membership Directory which is Part II of this issue.

Constitution and Bylaws

These have not been recently amended. They were last published in the April 1953 *Journal*. Reprint copies are available upon request to Society headquarters.

Officers of the Society April 1954



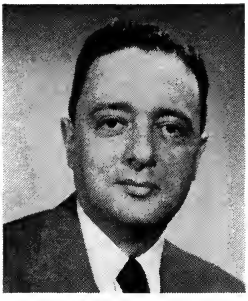
John G. Frayne
Executive Vice-President
1953–54

Herbert Barnett
President
1953–54

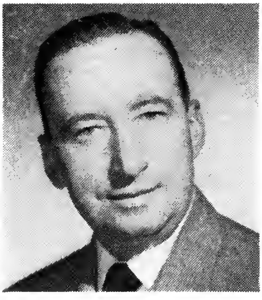
Peter Mole
Past-President
1953–54

Axel G. Jensen
Engineering Vice-President
1954–55

Norwood L. Simmons
Editorial Vice-President
1953–54



Barton Kreuzer
Financial Vice-President
1954–55

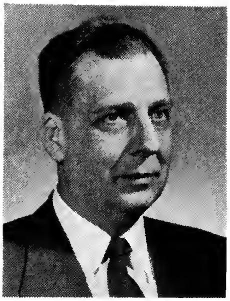


John W. Servies
Convention Vice-President
1953–54

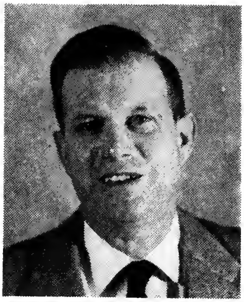
Edward S. Seeley
Secretary
1953–54

Geo. W. Colburn
Treasurer, 1954–55

Frank E. Carlson
Governor, 1953–54

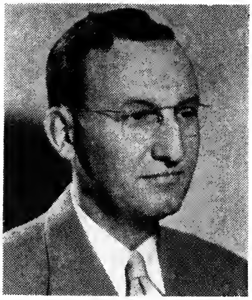


Gordon A. Chambers
Governor, 1953–54



L. M. Dearing
Governor, 1953–54

Wm. A. Mueller
Governor, 1953–54



Charles L. Townsend
Governor, 1953–54

Malcolm G. Townsley
Governor, 1953–54

Frank N. Gillette
Governor, 1954–55

Lorin D. Grignon
Governor, 1954–55

Ralph E. Lovell
Governor, 1954–55

Garland C. Misener
Governor, 1954–55

RICHARD O. PAINTER
Governor, 1954–55

REID H. RAY
Governor, 1954–55

PHILIP G. CALDWELL
Governor, 1954

EVERETT MILLER
Governor, 1954

JAMES L. WASSELL
Governor, 1954

OFFICERS AND MANAGERS OF SECTIONS

ATLANTIC COAST: Chairman, Everett Miller; *Secretary-Treasurer*, George H. Gordon; *Managers:* R. C. Holslag, George Lewin, Chas. W. Seager, M. H. Searle, R. T. Van Niman, J. Paul Weiss.

CENTRAL: Chairman, James L. Wassell; *Secretary-Treasurer*, Kenneth M. Mason; *Managers:* Howard H. Brauer, R. Paul Ireland, George Ives, Wm. P. Kusak, John S. Powers, Henry Ushijima.

PACIFIC COAST: Chairman, Philip G. Caldwell; *Secretary-Treasurer*, Edwin W. Templin; *Managers:* C. N. Batsel, A. C. Blaney, Hollis W. Moyse, Herbert Pangborn, Sidney Solow, Robert Young.

OFFICERS AND MANAGERS OF SUBSECTIONS

ATLANTA: Chairman, Ben Akerman; *Secretary-Treasurer*, Ivan Miles; *Managers:* Charles Beeland, C. F. Daugherty, Leigh Kelley.

SAN FRANCISCO: Chairman, Wm. A. Palmer; *Vice-Chairman*, Warren Andresen; *Secretary*, J. Lee Berryhill.

SOUTHWEST: Chairman, Ira L. Miller, Jr., *Secretary-Treasurer*, Walter W. Gilreath; *Managers:* John H. Adams, Hervey Gardenshire, Hugh V. Jamieson, Sr., Donald Macon.

STUDENT CHAPTER OFFICERS

NEW YORK UNIVERSITY: Chairman, Morton David; *Secretary-Treasurer*, Gerard Klein.

UNIVERSITY OF SOUTHERN CALIFORNIA: Chairman, Hal Arthur; *Secretary-Treasurer*, Roy Rogaway.

Board of Governors Meeting

The first 1954 meeting of the Board took place on January 28. In reviewing the Society's activities and plans for the coming year constant emphasis was put on the need for relating the services the Society would like to offer to the resources at its disposal. Services presently enjoyed by members should not be allowed to suffer, but any move to increase them must be contingent on an increase in resources. The problem of how to augment the latter therefore lay at the base of all the Board's deliberations.

Financial results of Society operations in 1953 were explained by Barton Kreuzer, former Treasurer and now Financial Vice-President. As will be seen from the financial statements published in this issue, operating expenditures for the year showed a deficit over income. This could be attributed to a number of factors: test-film income was below expectations, as was income from membership dues and subscriptions; *Journal* costs were up because more pages were published in 1953 than in any prior year and more copies printed; and convention costs had risen, aggravated by the light registration at the fall convention.

Reports on the **73d and 74th Conventions** were presented by J. W. Servies, Convention Vice-President. A proposal to change the number of conventions from two to one per year, as a possible economy measure, was heavily opposed and abandoned.

In the absence of Editorial Vice-President Norwood L. Simmons, Boyce Nemec, Executive Secretary, reported on **publications.** The *Journal* in 1953 had been by far the largest in the Society's history and had come very near meeting the members' wishes both in volume and in scope of technical coverage. Of several suggestions offered for increasing income from publications, three were accepted: the price of single copies of the Journal will be increased to $2.00 for each one-part *Journal* and $2.50 for special two-part issues, members being given a 10% discount; charges for authors' reprints will be increased 10%; and beginning with the July issue the *Journal* format will be changed and advertising will be published.

This last decision was a part of the program to increase the Society's resources and services and was largely based on the interest in advertising shown by the returns to the Membership Service Questionnaire (see July 1953 *Journal*). Many members will recall that advertising was a feature of the *Transactions* and *Journal* up until the last war. The change in format, which will be to an $8\frac{1}{4} \times 11\frac{1}{4}$-in. trim size, was conditioned by the value of accommodating a standard 7×10-in. advertising plate.

Engineering Vice-President Axel G. Jensen presented a report, the major items of which were covered in the Engineering Activities column in the March *Journal*. The Board approved for SMPTE sponsorship several proposed American Standards for forwarding to the American Standards Association.

The Board considered a proposal for the formation of a **Canadian Section** of the Society. Information is to be sought on numbers and location of members in Canada, and the matter reconsidered, if the prospects warrant it, at the next meeting.

Gordon A. Chambers reported that the special **Awards Study** Committee had completed its work. For the first time, a uniform schedule of procedures in connection with the bestowal of the Society's various awards has been prepared, and is to be incorporated in the Society's Administrative Practices.—*D.C.*

Announcement: Advertising in the Journal

The Society's Board of Governors has decided that the service offered by the Society to its members can be substantially improved by the inclusion of advertising in the *Journal*. Beginning with the July 1954 issue, advertisements will be carried as a regular feature.

In earlier days, the Society found that advertisements gave members a source of information on the availability of new equipment and services which could be profitably used in conjunction with the technical matter contained in the *Journal*. It was, in fact, not until the war years that advertising came to be dropped. That there is a real and widespread interest among members in its revival was clearly shown in the replies received to the Membership Service Questionnaire sent out to members in the early part of 1953. The results, published in the July 1953 *Journal* put advertising at the top of the list of suggested additions to the *Journal* content. Also, among the subjects most often cited by members as of major interest was New Products, a clearly related field.

The July 1954 issue will therefore see the *Journal* in a new format. It will be increased in size to $8\frac{1}{4} \times 11\frac{1}{4}$ in., and will take a standard 7×10-in. advertising plate, or the usual subdivisions thereof. Text will be in three columns. Rates, which may be subject to some small adjustment once the procedure becomes a matter of practice, will compare well with those of comparable technical publications:

¼ page	$ 62.50
½ page	125.00
1 page	250.00
3 pages, per page	225.00
6 pages, per page	212.50
12 pages, per page	205.00

There will be provision for the insertion of professional cards, for members of the Society only, at a yearly fee of $60.00. More detailed information for advertising managers will be circulated shortly. The Society's officers will greatly appreciate advice and suggestions in promoting and guiding the efforts to make this new source of the greatest utility and advantage to all members of our Society.

Section and Subsection Meetings

The January meeting of the **Central Section** was held at the Western Society of Engineers on the 21st. Prior to the meeting, a business session was held by the officers and members of the Section. Preparations were made for a Financial Operating Budget for 1954, and the decision was taken to send out future meeting announcements in the form of a newsletter. The Membership and Program Committees also met to lay plans for the coming year.

At the regular session, two papers were given. Thomas T. Hill, Chief Photographic Chemist of Ringwood Chemical Corp. (formerly Edwal Laboratories), outlined the basic chemistry of the photographic operation for motion-picture film processing. A description of the physical construction of film was provided and some time was spent discussing controls available with such chemicals and the precautions necessary to avoid difficulty in developer and fixing operations. Mimeographed copies of this paper are available on request from the Chairman or directly from the author at Ringwood Chemical Corp., Ringwood, Ill.

The second paper, "A History of Color Film Reproduction," was presented by Ray Balousek, President of Grossman-Knowling Co., Detroit. This paper consisted of two parts, the first being concerned with the historical highlights of color cinematography from the first two-color Kodachrome and two-color Technicolor imbibition process up to the present 35mm negative/positive color films. The second section of the paper reviewed problems in regard to color-slide animation, particularly with negative/positive films. Excellent illustrative slides were shown on all phases of this talk and also a slide film reviewing the historical processes.—*K. M. Mason*, Secretary-Treasurer, Central Section, 137 N. Wabash Ave., Chicago.

The Pacific Coast Section met at the RKO-Pathe Studios in Hollywood on the evening of February 16. Attendance was limited to 200 at each of two sessions, on a pre-reservation basis, and all reservations were taken.

The subject was the Tushinsky Process of variable anamorphic photography and projection. The process was presented by the inventors, Joseph and Irving Tushinsky, and was of particular interest since all the proposed applications were demonstrated on the large curved screen installed on the sound stage where the meeting was held.

As explained by the speakers, the process incorporated variable anamorphic lenses in the camera, the printer, the projector, or any combination thereof. Demonstrations were given with these various combinations at different aspect ratios, with the projector lens being made complementary to those introduced in the camera and printer. In addition, demonstrations were given where the overall combination of compression and expansion were not complementary. A considerable variation from the 1:1 ratio was found to be acceptable. In this respect, the Nutcracker Suite from Walt Disney's *Fantasia*, projected at a 3:1 screen aspect ratio, was found to be very effective.—*E. W. Templin*, Secretary-Treasurer, Pacific Coast Section, ℅ Westrex Corp., 6601 Romaine St., Hollywood 38.

The Southwest Subsection met jointly with the I.R.E. and A.I.E.E. in Karcher Auditorium on the Southern Methodist University campus, Dallas, February 19. Axel G. Jensen, Director of Television Research, Bell Telephone Laboratories, and SMPTE Engineering Vice-President, spoke on the present status of color television. Starting with a résumé of the color television hearings before the FCC in 1950–51, Mr. Jensen covered the many interesting developments that led up to the present system of compatible color television. A very worthwhile discussion followed the talk. Unusually bad weather kept attendance at this meeting to about 100.—*W. W. Gilreath*, Secretary-Treasurer, Southwest Subsection, 3732 Stanford St., Dallas, Tex.

Engineering Activities

Ten committees, listed below, are scheduled to meet concurrently with the 75th Convention in Washington, D.C. As usual, the meetings will be open to all and neither lack of committee nor Society membership will be a bar to participation in these deliberations.

Color
Film Dimensions
Film Projection Practice
High-Speed Photography
Optics
Screen Brightness
Sound
Television
Television Studio Lighting
Theater Television

An Engineering Committee Manual describing committee procedures, processing of American Standards and the overall Engineering operations is in a final stage of preparation and should be off the press shortly. This will be distributed to all committee members and to those interested parties who request a copy.—*Henry Kogel*, Staff Engineer.

Obituary

David P. Boyle, Consulting Engineer, died on January 6, 1954, at his home in Pacific Palisades, Calif., at the age of 36.

After graduating "cum laude" from Dartmouth College in 1940, Dave Boyle joined the Research Laboratory of Eastman Kodak Co. at Rochester and spent a year there before going to Washington to do research work for the Navy. At the outbreak of war he joined the Signal Corps, went to England, and worked there with the Royal Air Force on airborne radar. After further training at Bell Laboratories in the U.S. Dave took the latest air radar equipment to Guam, where it was effectively used by our bombers in destroying the Japanese oil refineries. Upon release from the Army he joined the Pathe Industries, and was there until the time of his death from cancer.

Book Review

Techniques of Television Production

By Rudy Bretz. Published (1953) by McGraw-Hill Book Co., 330 W. 42d St., New York 36. Television Series, Donald G. Fink, Consulting Editor. xii + 464 pp. + 10 pp. index. 377 illus. 6 × 9½ in. $10.00.

This book fills a long-felt need for information on the television production techniques, not only as they apply to large network-operated television stations but also as they pertain to the practices in small local stations.

The author visited 76 operating television stations from coast to coast, as well as two in Canada, and the practices in some of these stations are described. He also obtained material from many other television authorities, manufacturers and the television networks.

The book is well organized, easy to read, and is equally interesting to persons who have been engaged in television work, as well as those who are new to the field.

The complex problems of staff responsibility, camera handling, control-room operation, and switching and production problems resulting from technical limitations are well covered.

The chapters relating to lenses, mirrors and prisms, special effects, graphic materials, illusions and projection equipment are especially valuable to production personnel. The treatment is nontechnical and is easy to understand since excellent illustrations are utilized to supplement the text. The chapters on television scenery, make-up and lighting will be very useful to production and technical personnel. The chapters on audio and remote pickups provide good general information.

The reviewer believes that this book will be especially useful to all newcomers to television and a valuable reference source for those engaged in the art.—*R. A. Isberg* Television Consultant, 2001 Barbara Dr., Palo Alto, Calif.

New Products

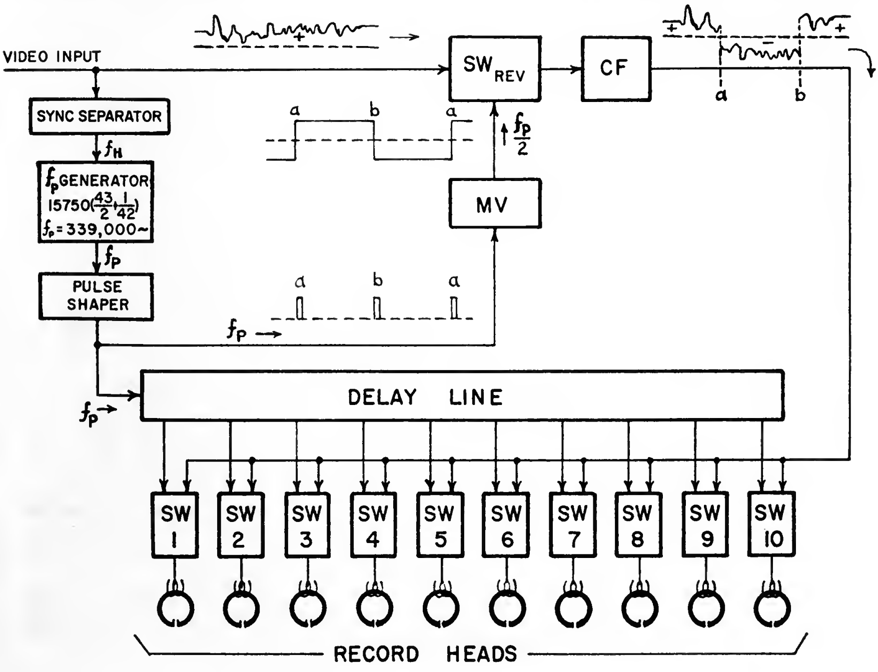
Further information about these items can be obtained direct from the addresses given. As in the case of technical papers, the Society is not responsible for manufacturers' statements, and publication of these items does not constitute endorsement of the products.

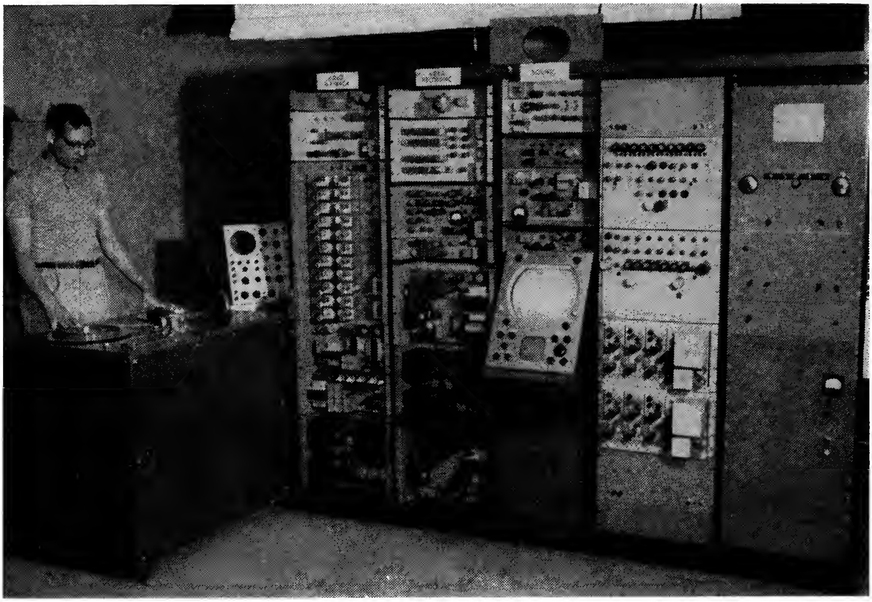
VTR (video tape recording), a new system of recording television signals on magnetic tape, has been announced by Bing Crosby Enterprises, Inc., Los Angeles. The new system is designed to conserve tape velocity and permit 15-min running time from reels of reasonable size. One-half in. or $\frac{3}{8}$-in. tape may be used, and the tape speed is 100 ips in either case.

Ten tracks are used simultaneously for video information; an eleventh track records vertical and horizontal synchronizing signals; and a twelfth carries the sound channel.

For recording, horizontal sync from the incoming video signal is transformed into a pulse which in turn operates a polarity-reversing switch affecting the signal at the pulse rate. The signal, alternating at 169 kc, is then applied to a series of ten switch units in parallel, and the pulse meantime applied to a delay line containing nine equally spaced taps. During the pulse period each switch in turn samples the video signal and passes a burst of current to its associated recording head. At the end of this sequence, the polarity of the input video signal reverses and each recording head is excited in the reverse manner.

An alternating signal is thus recorded on each





track, with both positive and negative halves representing bits of picture information up to 1.69 mc for the whole group of ten heads.

In playback, the sampling pulse is 0.15 μsec in duration but the highest sampling rate of the video signal is 0.34 μsec, giving 0.19 μsec of dead time between samples. By shifting the time of sampling of the entire system so that it is alternately delayed between zero and 0.19 μsec at a 15-cycle rate the field of the picture may be made up of twice as many samples, resulting in a high-definition picture containing detail well beyond that of a 3.39-mc image. Units which read only the peak value of successive samples are applied at the output of the video bus, thereby bringing the picture to an average energy level, the same as that of a customary signal. This "box-carring," or dot-connecting, device, when used with the 15-cycle shift, results in a picture having a fairly indeterminate high-frequency cutoff, lying between 1.69 and 3.39 mc.

Employment Service

These notices are published for the service of the membership and the field. They are inserted for three months, at no charge to the member. The Society's address cannot be used for replies.

Positions Wanted

By a Motion-Picture Industrial Engineer: 8 yrs planning plant expansion and improvement projects of film laboratories, including equipment procurement, contracting, expediting, bill-of-materials control, machine design, material handling, floor-plan layout, utilities. Familiar with cinematography, sensitometry, color principles, printing problems, mfg. processes. MIT-trained in mech., elec., indus. engineering. Esp. interested in Service Dept., producer liaison, or TV applications. Phone or write: F. L. Bray, DuArt Film Laboratories, 245 W. 55 St., New York City, PLaza 7-4580.

Motion-Picture Television Technician: 10 yr intensive skill and know-how related to 16-35mm cinematography, animation, recording (optical, tape, disk), editing, laboratory processing practice (black-and-white, color); also kinescope recording techniques; self-reliant; inventive; relocate if required; write: CMC, c/o Penning, 435 E. 74th St., New York 21, N.Y.

Electronics Engineer: B.S.E.E., 3 yrs chemical engineering, 2 yrs graduate work in physics. Currently working on Masters Degree. Engaged in gaseous electronics research, experienced in design and development of electronic instrumentation, installation and operation of automatic recording temperature control systems, vacuum system technique, maintenance and repair of all types of electronic equipment. 4 yrs retail business experience. Possess ability to write clear, concise reports. Interested in the motion picture, both artistically and technically. Desire position with organization in Los Angeles area preferably engaged in motion-picture production. Expect to be in Los Angeles area in late summer this year. Request interview. Member, IRE, SMPTE, Fla. & Nat. Soc. of Prof. Engs. Registered Engineer in Training State of Florida. Age, 28; unmarried. Write: Berel David Solomon, Box 274, Univ. Station, Miami, Fla.

Motion-Picture Producer-Director: Now employed in charge of motion-picture production for leading oil company. 18 yrs experience in production, script, direction, motion-picture photography, editing, scoring and recording of industrial, sales training, educational, travel and theatrical motion pictures. Highly experienced in low budget productions for industry. Available in near future; employer has been notified of desire for change to better position. Address inquiries to: A. P. Tyler, Box 2180, Houston, Tex.

Motion-Picture Cameraman: Wants position assisting editor or with production crew. College graduate, film production major, production experience prior to entering Service. Army cameraman for 2 yr in Arctic. Separation from Army July 16, 1954. Will consider temporary position and/or travel. Write Elliott H. Butler, 470 Audubon Ave., New York 33.

Positions Available

Permanent Position: Open for versatile 16mm cameraman familiar with all phases of industrial production. Write McLarty Picture Productions, 45 Stanley St., Buffalo 6, N.Y.

Motion-Picture Sound Mixer (male), GS-10: Require $5\frac{1}{2}$ yr experience in sound mixing for radio, disk recording and motion-picture production, of which least 3 yr must have been in mixing for motion-picture production, include experience with live dialogue, narration, music, sound effects, lip synchronization and re-recordings. $5500/yr. Obtain Form SF 57 at any first class Post Office or Government Agency; forward or deliver completed to Civilian Personnel Div., Signal Corps Pictorial Center, 35-11 35 Ave., Long Island City, N.Y.

Motion-Picture Asst. Director (male), GS-10: Require $5\frac{1}{2}$ yr progressively responsible experience in motion pictures, theatrical, television broadcast or radio broadcast production which has demonstrated the ability to perform in this position. Included in general experience must be at least $2\frac{1}{2}$ yr experience as a first assistant director in motion-picture production. $5500/yr. Obtain Form SF 57 at any first class Post Office or Government Agency; forward or deliver completed to Civilian Personnel Div., Signal Corps Pictorial Center, 35-11 35 Ave., Long Island City, N.Y.

Meetings

75th Semiannual Convention of the SMPTE, May 3–7, Hotel Statler, Washington

Society of Motion Picture and Television Engineers, Central Section (with Western Society of Engineers), May 13

Society of Photographic Engineers, Fourth Annual Conference, May 26–28, U.S. Hotel Thayer, U.S. Military Academy, West Point, N.Y. Some 35 titles have been scheduled. For information write: Anthony E. Salerno, c/o Pavelle Color, Inc., 533 W. 57 St., New York 19.

Society of Motion Picture and Television Engineers, Central Section (with Western Society of Engineers), June 10

American Institute of Electrical Engineers, Summer General Meeting, June 21–25, Los Angeles, Calif.

Acoustical Society of America, June 22–26, Hotel Statler, New York

American Physical Society, June 28–30, University of Minnesota, Minneapolis, Minn.

American Physical Society, July 7–10, University of Washington, Seattle, Wash.

Illuminating Engineering Society, National Technical Conference, Sept. 12–16, Chalfonte-Haddon Hall, Atlantic City, N.J.

2d International Symposium on High-Speed Photography, Paris, September 22–28, 1954. Arranged by the Association Française des Ingénieurs et Techniciens du Cinéma. Applications or inquiries should be addressed to the Secretary of the Organizing Committee, P. Naslin, Laboratoire Central de l'Armement, Fort de Montrouge, Arceuil (Seine), France.

Photographic Society of America, Annual Meeting, Oct. 5–9, Drake Hotel, Chicago, Ill.

American Institute of Electrical Engineers, Fall General Meeting, Oct. 11–15, Chicago, Ill.

76th Semiannual Convention of the SMPTE, Oct. 18–22, Ambassador Hotel, Los Angeles

77th Semiannual Convention of the SMPTE, Apr. 17–22, 1955 (next year), Drake Hotel, Chicago

The International Commission on Illumination is to hold its next international conference in Zürich, Switzerland, June 13–22, 1955 (*next year*). Offers of papers should be addressed to the Chairman of the Papers Committee (A. A. Brainerd), 1015 Chestnut St., Philadelphia 7. Manuscripts must be in the hands of the Central Bureau between Oct. 1 and Dec. 31, 1954.

78th Semiannual Convention of the SMPTE, Oct. 3–7, 1955 (next year), Lake Placid Club, Essex County, N.Y.

Committees of the Society

As of March 16, 1954

Administrative Committees

ADMISSIONS. *To pass upon all applications for membership, applications for transfer, and to review the Student and Associate membership list periodically for possible transfer to the Associate and Active grades, respectively. The duties of each committee are limited to applications and transfers originating in the geographic area covered.*

John G. Stott, *Chairman*, *East*, Eastman Kodak Co., Color Technology Div., Bldg. 65, Kodak Park, Rochester 4, N. Y.

Harry C. Milholland	Norman F. Oakley	Ethan M. Stifle

Geo. W. Colburn, *Chairman*, *Central*, 164 N. Wacker Drive, Chicago 6, Ill.

Carrington H. Stone	C. E. Heppberger	Robert E. Lewis

Edward H. Reichard, *Chairman*, *West*, 13059 Dickens St., North Hollywood, Calif.

Fred G. Albin	Everett E. Griffith	George R. Groves

BOARD OF EDITORS. *To pass upon the suitability of all material submitted for publication, or for presentation at conventions, and publish the* Journal.

Arthur C. Downes, *Chairman*, 2181 Niagara Dr., Lakewood 7, Ohio

D. Max Beard	L. D. Grignon	Pierre Mertz	J. H. Waddell
G. M. Best	A. M. Gundelfinger	C. D. Miller	D. R. White
G. R. Crane	C. W. Handley	J. A. Norling	C. W. Wyckoff
H. E. Edgerton	A. C. Hardy	H. W. Pangborn	
C. H. Elmer	C. R. Keith	B. D. Plakun	
C. R. Fordyce	G. E. Matthews	R. T. Van Niman	

EUROPEAN ADVISORY COMMITTEES. *To act as liaison between the general Society and European firms, individuals, and organizations interested in motion picture and television engineering. To report to the Society on such affairs in Europe, on new technical developments, and to assist the Papers Committee in soliciting papers for publication in the* Journal.

I. D. Wratten, *Chairman* (*British Division*), Kodak, Ltd., Kingsway, London, England

R. H. Cricks	W. M. Harcourt	L. Knopp	C. G. Mayer	A. W. Watkins

L. Didiée, *Chairman* (*Continental Division*), Association Francaise des Ingénieurs et Techniciens du Cinéma, 92 Champs-Elysées, Paris (8e), France

R. Alla	M. Certes	J. Fourrage	M. Terrus
R. Bocquel	J. Cordonnier	C. V. Jarrett	J. Vivié
L. Busch	S. Feldman	G. Mareschal	M. Yvonnet

FELLOW AWARD. *To consider publications of Active members as candidates for elevation to Fellow, and to submit such nominations to the Board of Governors.*

Frank E. Cahill, Jr., *Chairman*, Warner Bros. Pictures, Inc., 321 W. 44 St., New York 18

Herbert Barnett	J. G. Frayne	Everett Miller	N. L. Simmons
P. G. Caldwell	A. G. Jensen	E. S. Seeley	J. L. Wassell
Geo. W. Colburn	Barton Kreuzer	J. W. Servies	

HISTORICAL AND MUSEUM. *To collect facts and assemble data relating to the historical development of the motion-picture and television industries, to encourage pioneers to place their work on record in the form of papers for publication in the* JOURNAL, *and to place in suitable depositories equipment pertaining to the industry.*

John B. McCullough, *Chairman*, Conservation Dept., Motion Picture Assn. of America, Inc., 28 W. 44 St. New York 36

Lloyd Thompson — James Card

HONORARY MEMBERSHIP. *To search diligently for candidates who through their basic inventions or outstanding accomplishments have contributed to the advancement of the motion-picture industry and are thus worthy of becoming Honorary members of the Society.*

Gordon Chambers, *Chairman*, Eastman Kodak Co., 343 State St., Rochester 4, N.Y.

C. H. Dunning — P. T. Farnsworth — Barton Kreuzer — L. L. Ryder

JOURNAL AWARD. *To recommend to the Board of Governors the author or authors of the most outstanding paper originally published in the* JOURNAL *during the preceding calendar year to receive the Society's Journal Award.*

F. J. Kolb, Jr., *Chairman*, Eastman Kodak Co., 343 State St., Rochester 4, N.Y.

Paul Arnold — A. N. Goldsmith — J. H. Spray

MEMBERSHIP. *To solicit new members and to arouse general interest in the activities of the Society and its publications.*

A. Raymond Gallo, *General Chairman*, Quigley Publications, 1270 Sixth Ave., New York 20
J. B. McCullough, *Chairman*, Motion Picture Association, 28 W. 44 St., New York 18
Col. S. R. Todd, *Chairman*, 65 West Jackson Blvd., Box 103, Chicago 4
H. M. Fisher, *Vice-Chairman*, (De Vry Corp.), 3613 Chevy Chase Lake Dr., Chevy Chase 15, Md.
J. W. DuVall, *Chairman*, E. I. du Pont de Nemours & Co., 7051 Santa Monica Blvd., Hollywood 38
Forrest Jennings, *Vice-Chairman*, Color Reproduction Co., 7936 Santa Monica Blvd., Hollywood
George Rutherford, *Chairman*, *Foreign Membership Committee*, Toronto Camera Exchange, 293 Church St., Toronto, Ont., Canada
R. D. King, *Vice-Chairman*, 35 Boorool Rd., KEW E. 5, Victoria, Australia

(Under Organization)

Member Delegates

V. D. Armstrong	A. C. Davis	R. C. Holslag	Don Prideaux
H. C. Barr	C. H. Elmer	Bruce Howard	G. F. Rackett
P. E. Brigandi	C. R. Fordyce	H. V. Jamieson	H. I. Reiskind
H. P. Brueggemann	D. C. Gilkeson	Culver Johnson	J. W. Servies
G. A. Chambers	L. D. Grignon	L. R. Martin	W. M. Sheahan
R. W. Conant	G. R. Groves	W. C. Miller	S. P. Solow
J. W. Cummings	Sol Halprin	G. C. Misener	R. L. Sutton
C. R. Daily	R. N. Harmon	C. G. Nopper	J. E. Volkmann

NOMINATIONS. *To recommend nominations to the Board of Governors for annual election of officers and governors.*

G. C. Misener, *Chairman*, Ansco, Binghamton, N.Y.

C. H. Elmer	J. K. Hilliard	R. E. Lovell	R. H. Ray
C. E. Heppberger	W. B. Lodge	Peter Mole	E. I. Sponable

PAPERS. *To solicit papers and provide the program for semiannual conventions, and make available to local sections for their meetings papers presented at national conventions.*

W. H. Rivers, *Chairman*, Eastman Kodak Co., 342 Madison Ave., New York 17
J. E. Aiken, *Vice-Chairman*, 116 N. Galveston St., Arlington 3, Va.
Skipwith W. Athey, *Vice-Chairman*, General Precision Laboratory, 16 S. Moger Ave., Mt. Kisco, N.Y.
C. E. Heppberger, *Vice-Chairman*, 231 N. Mill St., Naperville, Ill.
G. G. Graham, *Vice-Chairman*, National Film Board of Canada, John St., Ottawa, Canada
R. E. Lovell, *Vice-Chairman*, National Broadcasting Co., Sunset and Vine, Hollywood 28
J. H. Waddell, *Vice-Chairman*, Wollensak Optical Co., 850 Hudson Ave., Rochester 21, N.Y.

J. A. Anderson	W. H. Deacy, Jr.	L. Hughes	B. D. Plakun
Mark Armistead	W. P. Dutton	P. A. Jacobsen	C. N. Shipman
D. Max Beard	B. T. Eddy	William Kelley	S. P. Solow
E. E. Bickel	C. H. Elmer	George Lewin	J. G. Stott
Richard Blount	Karl Freund	G. E. Matthews	W. L. Tesch
R. P. Burns	J. R. Glass	Pierre Mertz	Lloyd Thompson
M. H. Chamberlin	R. N. Harmon	H. C. Milholland	M. G. Townsley
P. M. Cowett	Scott Helt	W. J. Morlock	A. L. Wolff
E. W. D'Arcy	S. Eric Howse	H. W. Pangborn	R. L. Wolford

PROGRESS. *To prepare an annual report on progress in the motion-picture and television industries.*

C. R. Daily, *Chairman*, Paramount Pictures Corp., 5451 Marathon St., Hollywood 38

J. E. Aiken	Leo Busch	Anthony Frothingham	R. H. McCullough
Mark Armistead	H. S. Coleman	L. D. Grignon	Herbert Meyer
H. L. Baumbach	Gordon Craig	C. A. Hahn	J. A. Moses
E. A. Bertram	C. C. Davis	C. W. Handley	J. L. Pettus
Rudy Bretz	C. H. Elmer	Scott Helt	Fred Rich
P. E. Brigandi	Karl Freund	A. J. Hill	W. H. Ryan
I. M. Brown	E. C. Fritts	R. E. Lovell	M. G. Townsley

PROGRESS MEDAL AWARD. *To recommend to the Board of Governors a candidate who by his inventions, research, or development has contributed in a significant manner to the advancement of motion-picture technology, and is deemed worthy of receiving the Progress Medal Award of the Society.*

David B. Joy, *Chairman*, National Carbon Co., 30 East 42 St., New York 17

Max C. Batsel	F. N. Gillette	Peter Mole	Hollis Moyse

DAVID SARNOFF AWARD. *To recommend to the Board of Governors a candidate who has done outstanding work in some technical phase of the broad field of television or in any similar phase of theater television, whether in research, development design, manufacture or operation.*

L. L. Ryder, *Chairman*, Paramount Pictures Corp., 5451 Marathon St., Hollywood 38

R. L. Garman	T. T. Goldsmith	O. B. Hanson	W. B. Lodge

SUSTAINING MEMBERSHIP. *To solicit new sustaining members and thereby obtain adequate financial support required by the Society to carry on its technical and engineering activities.*

(Under Organization)

H. D. Bradbury, *Chairman*, RCA Victor Div., 411 Fifth Ave., New York 16

Geo. W. Colburn

SAMUEL L. WARNER AWARD. *To recommend to the Board of Governors a candidate who has done the most outstanding work in the field of sound motion-picture engineering, in the development of new and improved methods or apparatus designed for sound motion pictures, including any steps in the process, and who, whether or not a Member of the Society of Motion Picture and Television Engineers, is deemed eligible to receive the Samuel L. Warner Memorial Award of the Society.*

W. V. Wolfe, *Chairman*, RCA Victor Div., 1560 N. Vine, Hollywood 28

J. G. Frayne	D. J. Bloomberg	W. F. Kelley	H. E. Bragg

SMPTE Engineering Committees

(As of April 1, 1954)

The Engineering Vice-President, A. G. Jensen, has appointed the chairmen and committee members listed below to serve for his two-year term of office, January 1, 1954, through December 31, 1955.

Inquiries regarding committee projects or membership should be directed to Henry Kogel, Staff Engineer, at Society Headquarters.

COLOR. *To make recommendations and prepare specifications for the operation, maintenance, and servicing of color motion-picture processes, accessory equipment, studio lighting, selection of studio set colors, color cameras, color motion-picture films, and general color photography. (File C 1)*

J. P. Weiss, Chairman, E. I. du Pont de Nemours & Co., Inc., Parlin, N.J.

H. E. Bragg	A. A. Duryea	W. R. Holm	C. F. J. Overhage
O. O. Ceccarini	R. M. Evans	J. H. Jacobs	W. E. Pohl
R. O. Drew	L. T. Goldsmith	W. W. Lozier	G. F. Rackett
H. H. Duerr	A. M. Gundelfinger	A. J. Miller	L. E. Varden

FILM DIMENSIONS. *To make recommendations and prepare specifications on those film dimensions which affect performance and interchangeability, and to investigate new methods of cutting and perforating motion-picture film in addition to the study of its physical properties. (File FD 2)*

W. G. Hill, *Chairman*, Ansco, Binghamton, N.Y.

J. E. Aiken	E. K. Carver	W. E. Pohl	M. G. Townsley
E. A. Bertram	A. M. Gundelfinger	A. C. Robertson	W. E. Vary
W. C. Brandsma	A. J. Miller	N. L. Simmons	W. J. Wade

FILM-PROJECTION PRACTICE. *To make recommendations and prepare specifications for the operation, maintenance, and servicing of motion-picture projection equipment, projection rooms, film-storage facilities, stage arrangement, screen dimensions and placement, and maintenance of loudspeakers to improve the quality of reproduced sound and the quality of the projected picture in the theater. (File FPP 3)*

R. H. Heacock, *Chairman*, Radio Corporation of America, RCA Victor Div., Camden 2, N.J.

C. S. Ashcraft	William Hecht	E. E. Moyer	Harry Rubin
F. E. Cahill	C. F. Horstman	M. D. O'Brien	Ben Schlanger
L. W. Davee	W. H. Ingram	P. D. Ries	J. W. Servies
C. L. Greene	L. E. Jones	F. H. Riffle	

HIGH-SPEED PHOTOGRAPHY. *To make recommendations and prepare specifications for the construction, installation, operation, and servicing of equipment for photographing and projecting pictures taken at high repetition rate or with extremely short exposure times. (File HSP 5)*

R. O. Painter, *Chairman*, General Motors, Proving Ground Section, Milford, Mich.

H. C. Barr	J. S. Carroll	Kenneth Morgan	J. H. Waddell
D. M. Beard	H. E. Edgerton	Brian O'Brien	R. L. Wolford
C. S. Brasier	C. H. Elmer	D. H. Peterson	C. W. Wyckoff
M. E. Brown	Eleanor Gerlach	M. L. Sandell	A. M. Zarem
F. E. Carlson	C. D. Miller	Morton Sultanoff	

LABORATORY PRACTICE. *To make recommendations and prepare specifications for the operation, maintenance, and servicing of motion-picture printers, processing machines, inspection projectors, splicing machines, film-cleaning and treating equipment, rewinding equipment, any type of film-handling accessories, methods, and processes which offer increased efficiency and improvements in the photographic quality of the final print.* (*File LP 6*)

V. C. Shaner, *Chairman*, Eastman Kodak Company, 6706 Santa Monica Blvd., Hollywood 38, Calif.

V. D. Armstrong
H. L. Baumbach
F. S. Berman
H. P. Brueggemann
O. E. Cantor
G. A. Chambers
G. W. Colburn
I. M. Ewig
John Fritzen
T. M. Ingman
P. A. Kaufman
C. F. LoBalbo
E. M. Londre
J. A. Maurer
W. H. Offenhauser
W. E. Pohl
E. H. Reichard
J. H. Spray
J. G. Stott
Lloyd Thompson
Paul Zeff

MOTION PICTURE STUDIO LIGHTING AND PROCESS PHOTOGRAPHY. *To make recommendations and prepare specifications for the operation, maintenance, and servicing of all types of studio and outdoor auxiliary lighting equipment, tungsten light and carbon-arc sources, lighting-effect devices, diffusers, special light screens, etc., to increase the general engineering knowledge of the art; and to make recommendations and prepare specifications on motion-picture optical printers, process projectors (background process), matte processes, special process lighting technique, special processing machines, miniature-set requirements, special-effects devices, and the like, that will lead to improvement in this phase of the production art.* (*File MPSL 7*)

J. W. Boyle, *Chairman*, 139½, South Doheny Dr., Los Angeles 48, Calif.

Richard Blount
Karl Freund
C. W. Handley
M. A. Hankins
W. W. Lozier
D. W. Prideaux
Petro Vlahos

OPTICS. *To make recommendations and prepare specifications on all subjects connected with lenses and their properties.* (*File Op 8*)

J. L. Maulbetsch, *Chairman*, Kollmorgen Optical Corp., 347 King St., Northhampton, Mass.

F. G. Back
J. R. Benford
A. A. Cook
C. R. Daily
I. C. Gardner
Rudolf Kingslake
Grover Laube
J. A. Maurer
G. A. Mitchell
W. E. Pohl
L. P. Raitiere
L. T. Sachtleben
O. H. Schade
M. G. Townsley
W. E. Vary

SCREEN BRIGHTNESS. *To make recommendations and prepare specifications for the brightness of the motion-picture screen image, related factors such as ambient light and screen characteristics, methods of measurement in this field, and means for controlling and improving screen brightness.* (*File SB 10*)

F. J. Kolb, *Chairman*, Eastman Kodak Co., Kodak Park, Rochester, N.Y.

H. J. Benham
R. E. Birr
M. H. Chamberlin
B. S. Conviser
P. M. Cowett
E. R. Geib
L. D. Grignon
A. J. Hatch
L. B. Isaac
W. F. Kelley
Gerhard Lessman
W. W. Lozier
L. J. Patton
Justin Paulauskas
O. W. Richards
Leonard Satz
Ben Schlanger
Allen Stimson
C. R. Underhill
G. H. Walter
H. E. White
D. L. Williams
J. J. Zaro

16MM AND 8MM MOTION PICTURES. *To make recommendations and prepare specifications for 16mm and 8mm cameras, 16mm sound recorders and sound-recording practices, 16mm and 8mm printers and other film laboratory equipment and practices, 16mm and 8mm projectors, splicing machines, screen dimensions and placement, loudspeaker output and placement, preview or theater arrangements, test films, and the like, which will improve the quality of 16mm and 8mm motion pictures.* (*File SE 11*)

M. G. Townsley, *Chairman*, Bell & Howell Co., 7100 McCormick Rd., Chicago 45

F. L. Brethauer
F. E. Carlson
E. W. D'Arcy
G. A. del Valle
F. B. Dibble
C. R. Fordyce
J. L. Forrest
R. C. Holslag
H. J. Hood
W. W. Lozier
D. F. Lyman
J. W. Moore
W. H. Offenhauser
A. G. Petrasek
L. T. Sachtleben
Lloyd Thompson
R. T. Van Niman
W. E. Vary
W. R. Wilson

SOUND. *To make recommendations and prepare specifications for the operation, maintenance, and servicing of motion-picture film, sound recorders, re-recorders, and reproducing equipment, methods of recording sound, sound-film processing, and the like, to obtain means of standardizing procedures that will result in the production of better uniform quality sound in the theater.* (*File So 12*)

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THIS ISSUE IN TWO PARTS

Part I — April 1954 Journal

Part II — Membership Directory

APRIL 1954 • PART II

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Progress Committee Report

By CHARLES R. DAILY, *Committee Chairman*

CONTENTS

1953 will be remembered as a year of revolutionary change and progress in motion pictures and television. The advent of Cinerama and 3-D in the latter part of 1952 stirred the motion-picture industry into intense activity. The showings of Cinerama continued throughout the year and more theaters were added for its exhibition. 3-D pictures enjoyed considerable popularity for a time and thousands of theaters were equipped for showing them. With the improved methods now under development, 3-D may well establish itself in the future as a stable part of the entertainment industry. Stereophonic sound and sound placement spread from the Cinerama to 3-D and other showings. Theaters by the thousands took on the "New Look" by installing larger screens. Hundreds of CinemaScope installations were completed here and many abroad, introducing much wider screens, a new screen shape, anamorphic lens and single-film, 4-track stereophonic sound. Drive-in theaters increased in popularity and number, and the size of their new screens has been markedly increased due to higher reflective screen materials. The

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introduction of larger screens necessitated more lighting which led to improved lamphouses, carbons, lenses and screen materials with a higher light gain.

The need for larger negative images in the camera to offset the loss of definition from the larger screens was being met with a number of new camera designs. Cinerama and CinemaScope used larger negatives; and Paramount introduced the VistaVision process, using a special horizontal double-frame camera which makes possible a marked improvement in picture quality on standard release prints. *White Christmas* was the first production made by this new method. Todd-AO is testing a 65mm negative, and other larger-negative processes are under development.

The television industry has been equally active. Many new stations have been opened in the UHF band. The FCC approved the NTSC color standards proposal and excellent demonstrations of color TV have been held, including the transcontinental broadcast of color programs. The recording on magnetic tape of both black-and-white and color pictures was demonstrated — a truly revolutionary development. Kinescoping techniques were markedly improved and film projection equipments underwent a considerable change. Pay-as-you-see television and community distribution systems for television were inaugurated by Telemeter on a commercial basis in California and other areas.

To Make a Fuller Report

The material which follows has been obtained from numerous sources, and while it gives an overall picture of progress during 1953, it is far from being a complete record of what was accomplished during this eventful year. In order to make the report covering new developments for 1954 more complete, it is suggested that any company or individual send, during the year, a brief note describing the development in question to Society headquarters in New York; labelling it to be directed to the Progress Committee. If this procedure were followed by interested individuals all over the world, the next Progress Report could be much more informative and complete.

Stereoscopic Productions

General. Following the boxoffice success of *Bwana Devil* released late in 1952, many pictures were produced in 3-D and many new equipments and screens developed. In the United States, the productions used two 35mm cameras, two negatives, two prints and two projectors running in synchronism. Polarizing filters were used in front of the projectors and the audience used individual viewers. Most productions used pairs of regular 35mm motion-picture cameras in special mountings and the Norling[1] specially built camera was also used. Variable interaxial spacing and angle of convergence controls were provided.

Paramount[2] and Universal also used two-mirror systems, but arranged them so that both the interaxial spacing and convergence angle could be varied. Columbia[3] and Universal used two Mitchell cameras side by side, with one inverted in order to get the lenses close enough together. However, the most generally used mounting in all studios had one of the cameras straight ahead, with the other mounted at right angles; Ramsdell[4] patented an arrangement with the two cameras at right angles shooting through a semitransparent mirror which could be rotated slightly to change the convergence angle.

Warner Brothers developed an ingenious control system which incorporated a dial indication of the actual distance to the convergence plane for any lens and control setting. This considerably reduced alignment time on the set. The Research Council[5] proposed a simplified dial arrangement which served the same purpose, and this was adopted by several of the studios.

Based on recently discovered principles of stereoscopic vision, the Motion Picture Research Council[6] proposed an improved system for setting interaxial spacing and convergence angle to give the desired results when pictures were projected on theater-size screens. Most of the distortion and eyestrain due to these two factors were overcome. These recommendations were incorporated in a special calculator developed by the Research Council[7] and have been adopted by most of the major studios and other producers both in this country and abroad.

Many nondepolarizing screens were developed and installed. The generally higher brightness gain of such metallic screens helped overcome the severe light loss occasioned by the polarizing filters and the increased screen gain also aided in the improving of conventional pictures presented on wide screens.[8–11] Reel lengths were increased to 5000 ft so that only one intermission would be required. The accurate synchronization of the projectors lead to special interlocking equipment, both mechanical and electrical. Provisions for cooling and keeping the polarizing filters aligned in the booth were developed. The two light sources had to be carefully balanced to give the best results. Proper projection procedures were prepared by the Research Council[9] and distributed throughout the industry.

Synchronization problems were the hardest to solve and successful future 3-D showings will no doubt use single-film projection. Several single-film 3-D systems were developed. The Nord Corp. projection attachment uses a pair of prints side by side on a standard width of film. Projection through angled mirrors rotates the images, passes them through suitable filters and superimposes them on the screen.

The Moropticon system differs principally in the manner in which the images are rotated. With the somewhat reduced film areas and the loss in the mirrors, light levels at the screen are below those obtained with dual projectors.

Vectograph[12] is a promising possibility for superimposing a stereoscopic pair of pictures on a single film. Such film requires no filters at the projector and the effective light levels should be somewhat higher with a single projector than can now be obtained with two projectors. No extra booth equipment is required except a nondepolarizing screen and individual viewers.

Polarizing sheet filters were provided by Polaroid, Polalite, Polacoat and others.[13] More comfortable viewing will be obtained with the newer-type wire stiffening, and clip-on type of polarizing glasses.

One feature picture was produced in England in 3-D, *The Million Dollar Diamond* which was photographed with Raymond Spottiswoode's Spacemaster camera which claims very accurate positioning of the photographic pairs. The exhibition of 3-D pictures was quite limited in Germany and, as far as is known, no 3-D feature entertainment productions were produced in Germany. However, considerable progress was made in the use of 3-D techniques for research and scientific work, particularly 3-D X-ray pictures.

3-D Polarizing Materials. Viewers and filters of many types were produced. Polyvinyl alcohol-iodine types were distributed by the Polaroid Corp.,[13] and the Polalite Corp. in the United States, and by Mitsubishi in Japan. The Polacoat Co. used oriented dichroic dyes on a plastic base.

Vectograph. Progress on the Vectograph single-film process was reported by Polaroid Corp.[12]

Alignment Techniques for Theater Projectors. For the projection of 3-D pictures using two mechanical or electrical interlocked projection machines, the Polaroid Corp. developed two types of 3-D synchronization monitors.[14] The electronic Model 21 monitor shows on an easily read meter which film, if either, is lagging and by how much. Errors as small as $\frac{1}{10}$ frame or as large as 5 frames are automatically indicated. The simpler stroboscopic Model E monitor was also developed and over a thousand are in use. The Polaroid Corp. also developed a 3-D synchronization control switch[14] to eliminate synchronization error without interrupting the show. They also introduced dichroic polarizing filters tinted red and green for use in the booth to give a gross indication of lead or lag with one projector in respect to the other.

Several single-film systems were developed using two images on the same piece of film. None of these single-film systems has yet received commercial acceptance in the professional 35mm entertainment field. The SMPTE and Motion Picture Research Council issued alignment test films. The MPRC also designed a new calculator to simplify camera alignment in photography in 3-D pictures.

16mm Stereoscopic Projection

Various equipments are now available for synchronizing two 16mm projectors for 3-D work. Bolex, Elgeet and Nord have developed camera attachments for single-film photography in 3-D.

A constant-speed device for synchronization of two 16mm projectors was built by Bauer,[15] Stuttgart, and used for special showings of *House of Wax* on 16mm in Holland.

Wide-Screen Installations

During 1953 thousands of theaters installed much larger screens. In many cases these filled the entire proscenium arch and pictures were then shown at the various aspect ratios suggested by the studios supplying the film. Audience reaction to the larger screens was good and at year's end it seemed quite certain that the larger screens had become established as a fixed part of theater construction.

In order to increase the amount of light reflected to the audience, and also with the stimulus of 3-D, many of the new screens used an aluminized finish. Some had the aluminum surface sprayed on. Others had the aluminizing material built into the screen material itself, some had a semilenticular surface and others had a complete lenticular embossed surface which improved both the lateral and vertical distribution of light to the audience. The larger screens required that more light be provided from the booth, and toward this end new lamphouses and carbons were made available to markedly increase the light output. Also introduced to reduce heat at the film were air-cooling systems and interference-type heat filters which reflected unwanted heat before the light beam reached the film. Better and higher-speed lenses were introduced by a number of manufacturers. Following the precedent set by Cinerama, stereophonic and peripheral sound equipments were installed in many houses.

Drive-Ins

Approximately 4000 drive-in theaters were in service at the end of the year and many more were under construction or on the drawing board. Following the lead of the large-screen installations in outdoor theaters, and coupled with the improvement in reflective screen materials, many of the newer drive-ins are being built with much larger screens than heretofore. As an example, the 970-car LaMirada Drive-In at Downey, Calif., opened in November 1953 with a screen 65 ft by 85 ft. The entire screen is tilted toward the audience 8° from the vertical.

The screen is of an entirely new design using vertical flutes cast into a plaster surface. The basic design of the curvature of the flutes was worked out by the Motion Picture Research Council. After sealing, the plaster surface is painted with the proper type of aluminum paint which has a light gain of $2\frac{1}{2}$ and a proper vertical distribution lobe. The flutes give good horizontal distribution. The plaster face is applied to 1-in. thick lightweight aggregate-type concrete 4- by 8-ft panels, steel-reinforced. It is understood that experiments are now under way with extruded aluminum sheets with the vertical flutes embossed into the material. Some new drive-in screens are curved and many are being planned with much larger dimensions, generally with an aspect ratio of approximately 2 to 1.

Cinerama

Cinerama, the first of the wide-screen systems, demonstrated clearly the audience appeal of peripheral vision effects. In this respect the process has gone well beyond other developments which followed. Supplementing the new screen approach with stereophonic sound yields a medium which continues to maintain unusual audience appeal. By the end of 1953 nine theaters throughout the country were showing the Cinerama film, and more installations were in progress.

The development of Cinerama established the concept that real peripheral effects require true wide-angle photography projected on a deeply curved screen of sufficient size to approach encompassment of the audience, within practical limitations. The screen must be illuminated at normally experienced levels, or better, maintaining good light distribution and picture resolution over the entire screen area. Installed in a theater of appropriate design, a high degree of intimacy and feeling "a part of the picture" is achieved.

Three separate picture films are employed throughout the process and are so projected as to present a continuous scene. There is necessity for very accurate control of every step in the process from camera to screen to assure accurate registration of the three separate images. The three light sources must be evenly matched and provide uniform illumination over the screen segments to avoid objectionable variations near the joint area of adjacent pictures.

Although performance quality in respect to these requirements was acceptable in the initial Cinerama presentation, it is recognized that increased picture stability, improved light distributions and joint area blending is desirable in future productions. A second production now in process is expected to reflect considerable progress in these matters.

Stereophonic Sound

The R-8 3-track magnetic sound reproducer was developed by Westrex for separate sound-film reproduction which was used to provide stereophonic sound with 3-D and other 35mm theater release prints during the year (Fig. 1). Westrex also developed the penthouse modification of the RA-1035 magnetic recording system for 3 or 4 tracks. The magnetic heads are the plug-in type and are furnished for 3-track ASA position, 4-track CinemaScope master or 4-track CinemaScope release position. This adds facilities for RA-1467-A magnetic recorder now widely used (Fig. 2). Westrex developed the RA-1517-B triple-track, double-flywheel, stereomagnetic recorder. This unit has low flutter content, and high volume range and signal-to-noise ratio.

The RCA PG-300 Stereophonic Sound System consisted of the MI-9030 separate triple-track magnetic sound reproducer with 5500-ft magazines, the unit being selsyn motor interlocked with the picture projector. Triple-channel, 70-w amplification was used with three sets of stage speakers. Kinevox, Inc., produced theater reproducing sound systems for the Natural Sound Corp. of Hollywood. Altec developed magnetic stereophonic reproducers using the triple-track separate magnetic film for

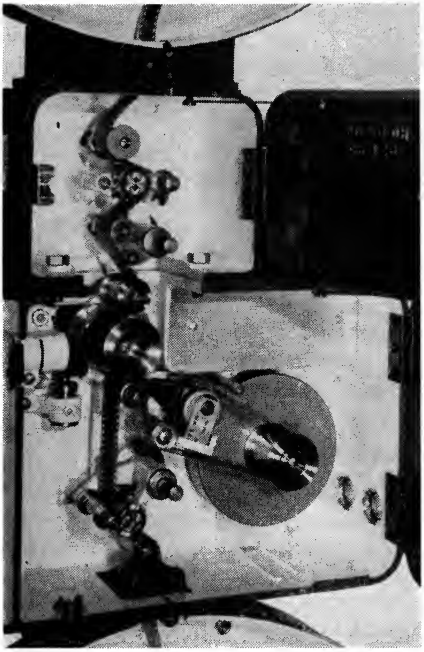

Fig. 1. The Westrex R-8 three-track, double-flywheel magnetic reproducer for separate sound film reproduction, shown with dummy projector.

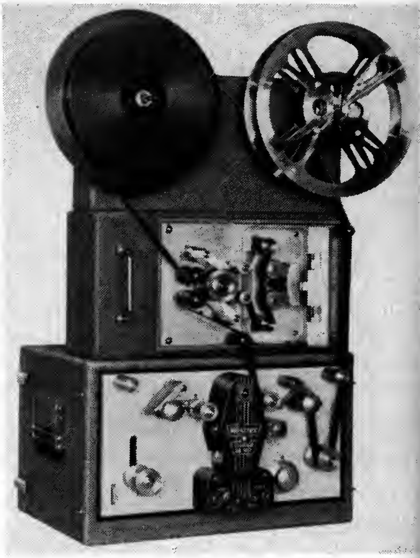

Fig. 2. The Westrex Penthouse stereomagnetic recorder.

3-D pictures beginning with Warner Bros. *House of Wax*. Siemens-Klangfilm and Philips developed complete systems of amplifier and loudspeaker equipments for stereophonic sound reproduction.

Sound-Placement Systems

The M-G-M-Fine sound-replacement system, using a standard optical release print, has been demonstrated. This system uses several subsonic frequencies recorded in the sound-track areas to control the gain of the amplifiers of each loudspeaker channel. Complete control of the placement of sound from the stage or auditorium horns is thereby achieved

The Dorsett Laboratories of Norman, Okla., have devised an inexpensive system of controlled loudspeaker switching wherein the sound from a standard optical release print from the normal center-stage loudspeaker is moved to the left or right, or to both, and/or to the peripheral auditorium loudspeakers. The switching cues are in the form of a binary code marked into both sprocket-hole areas. When optically scanned, the code signals operate switching relays. This system of sound placement is used in several theaters in Oklahoma and Texas. Standard, single-track optical release prints are cued for use with this system by the Dorsett representatives.

CinemaScope

The following description was submitted by Lorin D. Grignon of Twentieth Century-Fox:

CinemaScope, a totally new means of presenting motion pictures, developed by Twentieth Century-Fox Film Corp., was first shown to the public during 1953. It is a coordinated combination of known techniques, improved or modified to

›etter suit the process and delivered to he theater on a single composite film of ıew design. Uniquely, CinemaScope vas conceived and engineered, standards vere established, the manufacturers were ›rganized and the system was promoted n less than ten months from the time of ›reliminary tests to the public release of *The Robe,* September 16, 1953. To the ıudience it means only a picture of vidth approaching peripheral vision vith stereophonic sound, but several ·ngineering advancements were re- ıuired.

The wide picture aspect ratio of :.55 : 1 is realized on 35mm film by the ıse of anamorphic lens systems of a ıorizontal factor of 2 for the taking lens ›n the camera and the projector attach- nent. These lens systems are based on he work of Prof. Henri Chretien of 'rance in the late 20's and early ›0's,[16,17] modernized and improved for CinemaScope by the Bausch & Lomb[18] :-in. to 6-in. focal lengths, and when ap- ›lied correctly to these lenses doubles he horizontal angle of view without ffecting the vertical direction. The ilm image appears in correct vertical ›roportions but is squeezed in the hori- ontal direction. The projector at- achments are available in two sizes o fit the two standardized diameters of ›rojector lenses currently available. The projector anamorphics exactly re- tore the horizontal structure of the image o natural proportions. During the ear, Bausch & Lomb delivered over 00 camera and over 4000 projector ttachments. Additionally, Bell & Iowell, in the United States, British)ptical & Precision Engineers, Ltd., in ngland, Société Technique d'Optique t de Photographie in France; I. D. Möller-Optische Werke, GmbH, and Carl Zeiss in Germany; Officien Galileo e Milano, S.P.A., in Italy; Bausch & omb A.B., in Sweden; and Nippon ogaku K.K., in Japan, started manu- cture.

CinemaScope provides for full 3-channel stereophonic sound using essentially the methods described in the *Journal.*[19–22] Three independent soundtracks are used on the release film for theater reproduction by three amplifiers and loudspeaker systems. The stereophonic system is augmented by signals, from a fourth soundtrack, which are reproduced from loudspeakers mounted on the walls of the theater, to surround the audience with sound when appropriate to the scene. When the full capabilities of the system are used, sound enhances the wide picture so as to provide a practical approach to audience participation. Also recorded on the fourth track, simultaneously with the signal to be reproduced, is a constant-level signal of 12 kc which operates sensing and switching circuits in the theater to activate the fourth channel; when there is an absence of 12 kc, the surround reproduction channel is muted to assure that no background and random noises from the surround loudspeakers detract from the reproduction from the screen loudspeakers.

The new positive release film, of standard 35mm width, offers a balanced design providing more usable film area for picture and sound by means of a reduction in perforation dimensions. The result of extensive tests and consideration of all factors, technical and economic, was a perforation 0.073 by 0.078 in. spaced 1.127 in., center-to-center.[27] The hole is a Dubray-Howell perforation (ASA-PH22.1-1953)[23] of reduced width. New sprockets having teeth of 0.040-in. face width spaced axially 1.125 in., center-to-center, on a pitch diameter of 0.953 in. (dimension B, ASA-PH22.36–1954)[24] are recommended for use with CinemaScope film. The new sprockets operate equally well with the new or any presently used positive film and, in either situation, film life is increased.

The last several years have brought the use of magnetic materials for sound recording and reproduction into very wide use in all communication fields, other than motion-picture release, by virtue of numerous basic superiorities. CinemaScope presented an opportunity to introduce magnetic soundtracks advantageously into the theater field; accordingly, magnetic materials are striped upon the picture print, after processing, to create the composite sound and picture release print. Although of lesser width than the conventional optical release tracks, superior signal-to-noise ratio is obtained and the reproduced frequency characteristics can be extended to 8 kc without significant loss. The three principal tracks are of 0.063-in. width; the fourth track is of 0.029-in. nominal width.[27] Magnetic coating machinery has been developed by Reeves Soundcraft, Bell & Howell, Eastman Kodak, and Pyral of France. Minnesota Mining is presently developing a means to laminate solid magnetic tape materials onto 35mm film.

The use of multiple magnetic tracks demanded a new reproducer design.[25–27] It has been found universally convenient and advantageous to design and manufacture a wholly new unit to be mounted on the projector between the projector mechanism and the upper magazine. The problem of conversion parts for the many types of soundheads is thereby obviated and the performance, and use, of optical or magnetic scanning systems is not compromised in any way. All of the new reproducer attachments are film driven, have good flutter performance, satisfactory freedom from sprocket-hole modulation and are designed for adaptation to a large variety of projectors. One was used both as a recorder and reproducer to make and project the first composite film demonstration in CinemaScope in August 1953. Approximately 1200 theaters were fully equipped by year's end. Manufacturers in this country in full-scale production of theater equipments are: International Projector Corp., RCA Victor Div., Westrex Corp., Altec Lansing Corp., Ampex Electric Corp., Magnasync Manufacturing Co., the Ballantyne Co., Motiograph Co. and Century Projector Co.

In the foreign field, sound equipment was manufactured by G.B.-Kalee Ltd., RCA Photophone, Ltd., Sound Equipment, Ltd., Western Electric Co., Ltd., in England; Brockliss-Simplex, S.A., Westrex Corp., Etablissements Charlin, S.A., Compagnie Radio-Cinema, in France; Zeiss-Ikon A.G., Siemens-Halske Aktiengesellschaft, in Germany; Cinemeccanica S.P.A., Compagnia Generale di Costruzioni Cinematografiche e Radioelettroniche, Ing. Angelo Fedi S.A., Microtecnicca S.P.A., Officine Pio Pion, Officine Prevost, in Italy; Aga, in Sweden; Produit Perfectone S.A., in Switzerland; and N. V. Philips, in The Netherlands.

The large picture used with CinemaScope would suffer from lack of sufficient brightness unless the available projector light could be made more effective. Consequently, as a part of the CinemaScope "package," Twentieth Century-Fox engineered, developed and put into production a lenticular screen material available in two basic patterns. The screen surface is composed of small precisely embossed optical elements to reflect perpendicularly incident light rays within a useful vertical included angle of 60° and a horizontal angle of 100°. Within these limits the reflection factor is relatively uniform providing good viewing from all seats of the average theater. By this device, the apparent screen brightness, with a given incident intensity, is increased by two times. One pattern is used for essentially head-on projection and the other, a tilted element pattern, is useful for high-angle projection. In all installations it has been found desirable to hang the screen on a curve whose radius is that of the projector throw. The screen carries the trade name of Miracle Mirror. This screen material,

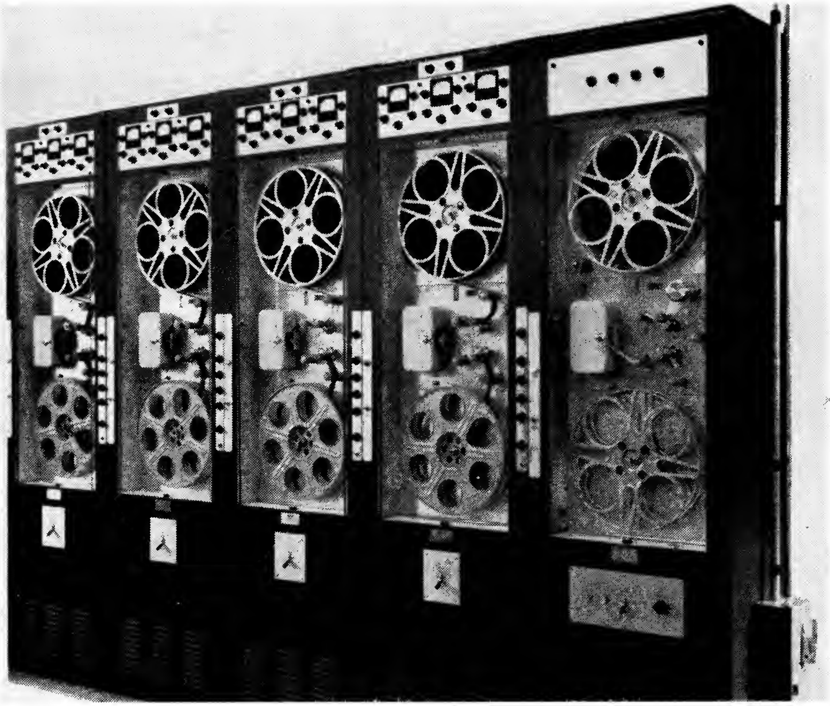

Fig. 3. The Westrex CinemaScope Sound Printer

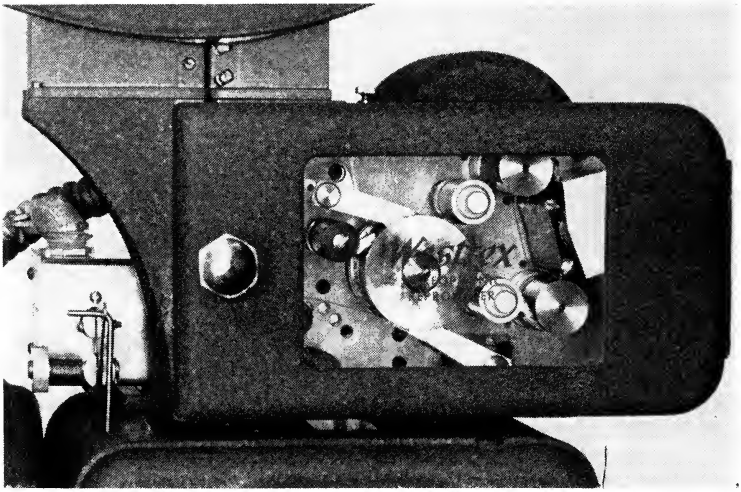

Fig. 4. The Westrex R-9 stereophonic four-track magnetic reproducer. Operating side closed.

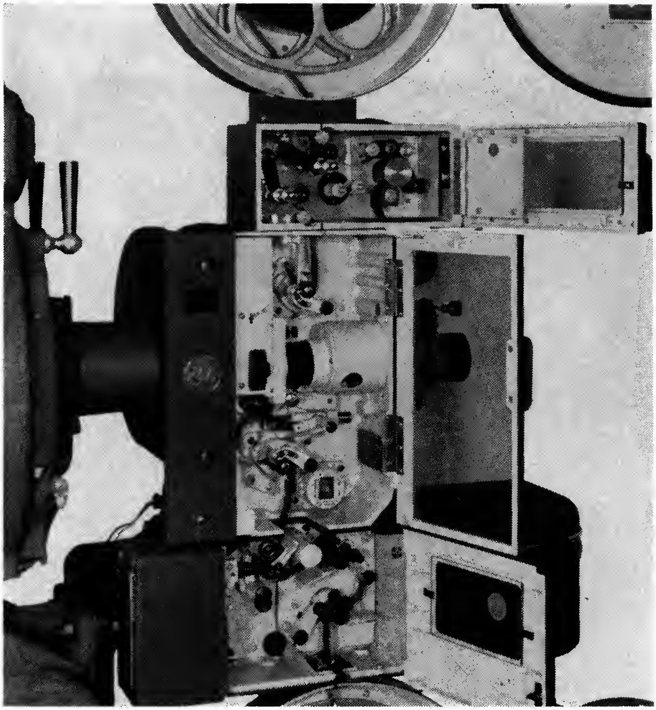

Fig. 5. The RCA CinemaScope sound system.

because of metallic reflection characteristics, is excellent for 3-D projection and hence is universal in application.

Screens are also being made abroad by A. R. Brackell, in Australia; British Optical & Precision Engineers, Ltd., in England; Michel Avenard, in France; Siemens-Halske Aktiengesellschaft, in Germany; Cinemeccanica S.P.A., in Italy; Jose Jover S.A. and Industria Electronica S.A., in Spain; and A. S. Nils Nessim, in Sweden.

Between September 5 and December 31, 1953, approximately 5,000,000 ft of release film had been produced and put into use in the domestic and foreign markets. This footage was represented by four feature productions, a number of short subjects and an industrial film. Using the same methods, other studios and independent producers were making features for general release in 1954.

CinemaScope Equipment

Westrex developed a release "printer" for multiple-track recording on striped theater prints for Twentieth Century-Fox Film and M-G-M. This printer, an adaptation of the Westrex RA-1506 recorder[28] reproduces four magnetic soundtracks from a master negative film and records four tracks on each of five composite release prints in one operation. An RA-1505 cabinet-type re-recorder and five RA-1506 recorders are used (Fig. 3). Westrex developed the R-9 penthouse reproducer (Fig. 4) for theater projectors.[25] It uses two impedance drums, tight film loop, and the well-known Davis-drive and flutter sup-

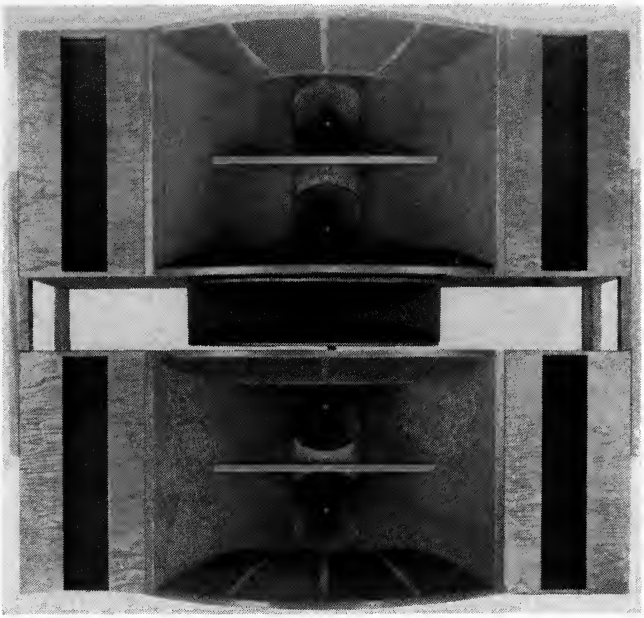

Fig. 6. RCA Stereoscope speakers.

pressor. An idler-roller permits adjustment to various lengths of film paths required for different makes of projectors.

Altec designed and manufactured several hundred penthouse reproducers and complete stage and auditorium surround speaker, amplifier and change-over systems.

RCA developed a complete sound system for CinemaScope (Fig. 5), including a "button-on" 4-track magnetic head cluster, film-driven soundhead, amplifier and suppressor panel.[26] Where booth space permitted, 5500-ft magazines were installed. The RCA Wide-Arc Lamp can operate 10-mm Hitex positive carbons at 135 amp. The new-type "Ubangi" stage speakers (Fig. 6) have excellent fidelity and coverage.

Motiograph introduced the AAA magnetic penthouse reproducer which uses a tight-loop film transport system, a minimum of magnetic material in the assembly, a tilt top to space the upper magazine away from the front wall and a "snubber" roller to reduce or eliminate film damage at the start of a reel.

Magnasync is producing the Magnaphonic PH-1435 penthouse reproducer (Fig. 7) for use with CinemaScope. It is protected against magnetic flux patterns generated by the projector motor and remote "dowser" solenoid. The WC-435 preamplifier group protects the side-wall speakers from the 12-kc control frequency. A master ganged fader for the three stage speakers, power supplies and a series of power amplifiers complete the stereophonic reproduction system.

Ampex developed three series of stereophonic playback equipments for CinemaScope motion pictures: Super systems, with a bank of preamplifiers for each projector and complete electronic change-over; DeLux systems with all protection features of the Super, but with manual change-over; and Master systems with extensive protection fea-

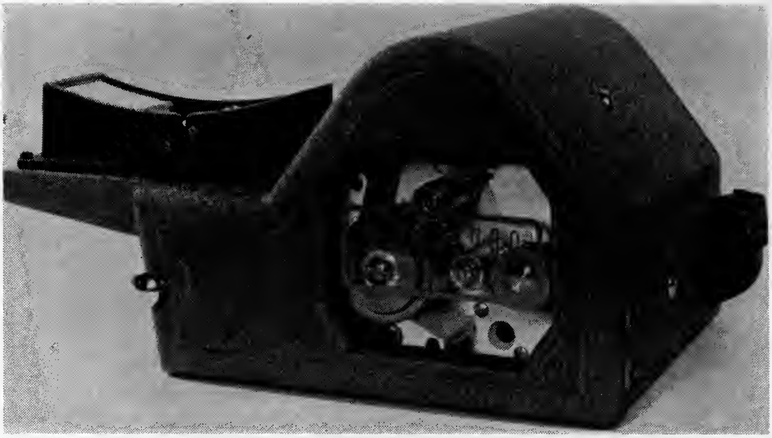

Fig. 7. Magnasync Penthouse Reproducer PH-1435.

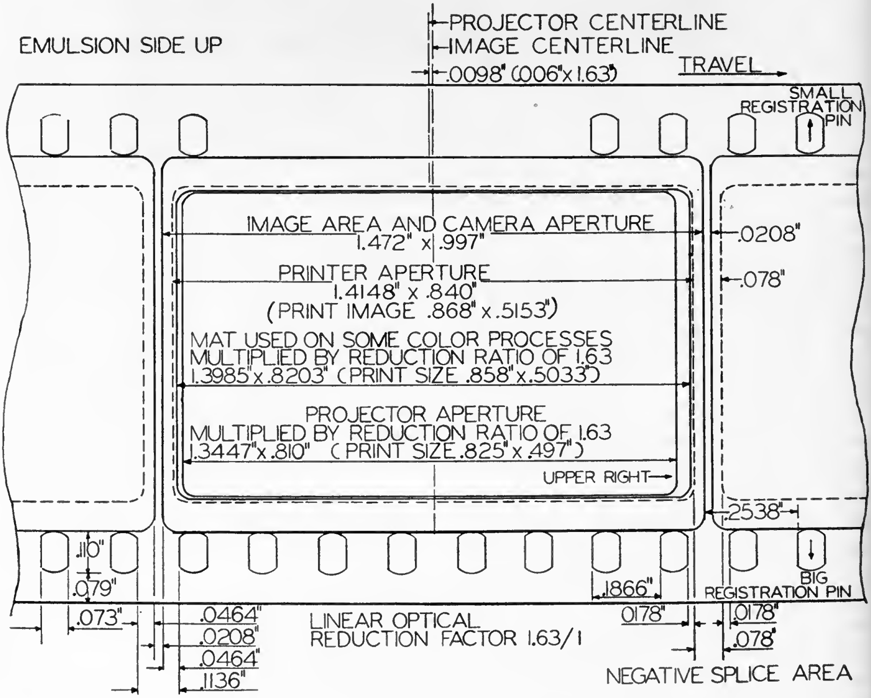

Fig. 8. VistaVision Camera frame dimensions, shown for aspect ratio of 1.66 : 1. Height appropriately reduced for aspect ratio of 1.85 : 1.

tures, but great simplicity, for maximum compactness and economy. A new line of theater loudspeakers was manufactured by Ampex under license from James B. Lansing Sound, Inc. G.B.-Kalee, RCA and Western Electric have produced excellent magnetic recorders and multitrack apparatus in England. In Germany,[29] the Bauer, Philips and Zeiss-Ikon factories have developed all sound and projector accessories for CinemaScope and other anamorphic processes. Installation is proceeding slowly in Germany because of the reported high investment required under present boxoffice conditions.

VistaVision

Paramount introduced the VistaVision process during the latter part of 1953. The most important feature of this new photographic system is the use of a large original negative in the camera, coupled with a substantial optical reduction to obtain standard release prints. Since the grain and resolution of a negative are much poorer than print materials, the use of the large negative produces a marked reduction in grain as seen on the theater screen coupled with a considerable increase in resolution. Release prints will carry a single optical track and can be played on any standard theater equipment, without modification, anywhere in the world. The photography is being composed for best projection at an aspect ratio of 1.85:1 but sufficient latitude has been allowed for projection at standard aspect ratios of 1.33:1 up to 2:1. Higher aspect ratios are not recommended. Figure 8 shows the VistaVision camera frame dimensions for an aspect ratio of 1.66:1.

White Christmas was the first feature production completed in the VistaVision process. Using standard 35mm negative in a special camera, a double-frame area is exposed which has an area $2\frac{1}{2}$ times larger than that used in standard cameras. Standard camera lenses which will cover the double-frame image are used in a special camera,[30] originally known as the Lazy 8, which has the negative travel horizontally through the camera. A negative area 1.472×0.997 in. is exposed. This special camera is equipped with a remote-controlled focusing device and a remote-controlled finder. The negative is handled in the standard manner through normal developing machines. An optical printer rotates the image the required 90° and reduces the image to standard release-print size. The release prints use standard positive perforations.

Todd-AO[31]

The wide-angle photographic process developed by Dr. Brian O'Brien for 65-mm film is the basis for the Todd-AO Corp. entrance into the wide-screen field. While not yet publicly released, this system is said to approach Cinerama in spectacular presentation, using, however, a single camera and projector! Ampex produced a series of record and playback mechanisms for the Magna Theatre Corp. to be used with the Todd-AO process. Magnetic record and synchronized playback machines of multichannel construction were built using 35mm sprocketed magnetic film. These were used for a number of private showings in Buffalo and New York.

Magnetic Striping

The four magnetic stripes used on CinemaScope tremendously expanded the use of striped magnetic sound films. Reeves Soundcraft produced a new striping machine (Fig. 9) for Twentieth Century-Fox Film which applies the four magnetic soundtracks to the color release prints at 150 ft/min. The machine uses the familiar method of flowing a suspension of magnetic oxide onto the film from a properly shaped and calibrated orifice.

Reeves Soundcraft have made available prestriped raw stock in a variety of

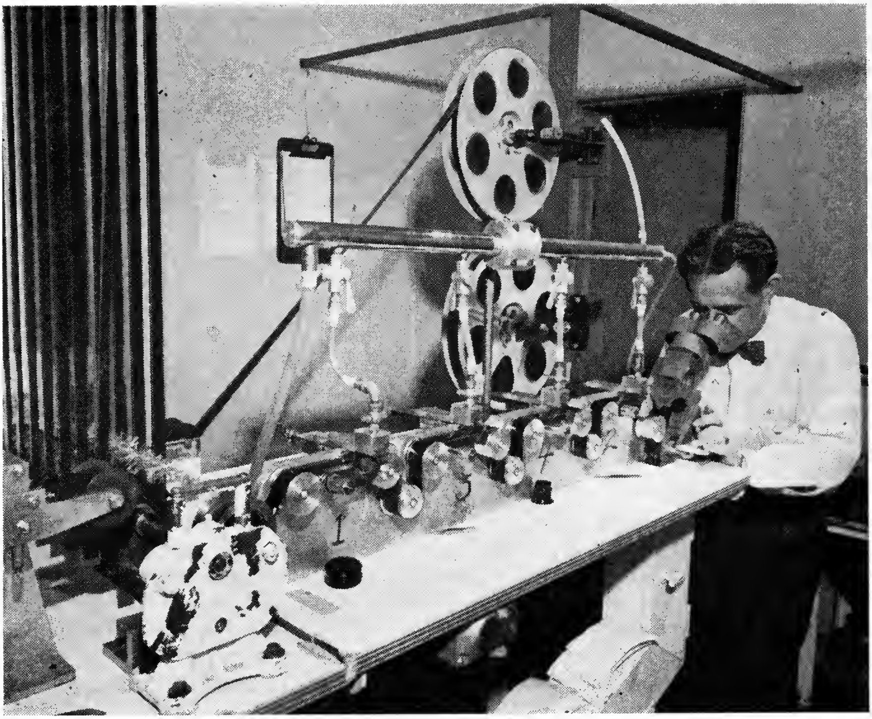

Fig. 9. The Reeves 35mm "Magna-Striper" installed at Fox Laboratories.

combinations, including a 35mm and 16mm sound-recording negative, Panchromatic and certain reversal color films. The sound-recording material is used by Columbia and others to record simultaneously an optical track and a magnetic track on the same film. The optical track is then used in editing and the final mix is made from the magnetic stripe, thus preserving the quality advantage of the magnetic system for the final mix. The prestriped negative materials are expected to prove useful for newsreels and similar uses where time does not permit the striping after editing and for classified work where the film must not be permitted out of the hands of the agency responsible.

The Minnesota Mining process, which transfers a magnetic coating from a temporary tape support to the film, was improved during the year by the addition of a pretreatment process which permits the stripe to adhere on either emulsion or base side of the film, and to film of any age or previous history. Commercial field trials have been run on this process at the Calvin Laboratories, Kansas City, Mo., and at McGeary-Smith Laboratories in Washington, D.C. Tracks of any width between 0.025 in. and 0.125 in. can be striped at 100 ft/min.

The Minnesota Mining Tape #125 is a new full-coated film stock for original recording and editing work. The "high-output" oxide coating increases the output about 10 db and has recording characteristics similar to the #120 "high-output" magnetic tape introduced in 1953.

In the foreign field, Pyral, of Paris, have installed striping equipment in a number of countries to support the use of 16mm magnetic-sound projectors in those countries. Pyral have improved their equipment during the year by the addition of an electromagnetic thickness-measuring device, which enables the operator accurately to control the thickness of the stripe as it is being applied.

In Germany, equipment has been installed for striping of CinemaScope film and striping is being done on 16mm film for television recording and on 8mm film for amateur use.

Optical Developments

The Hanovia Chemical & Mfg. Co. announced the first commercial production of optical-quality fused quartz in the United States. In addition to providing the optical industry with an additional source of fused quartz for use in ultraviolet transmission systems, it is expected that the electronic engineers will make use of this material for ultrasonic delay.[32]

Rudolf Frerichs announced new optical glasses with good transparency in the infrared. These glasses, which are being developed to a production stage by the Servo Corp. of America, have been previously reported in the literature without benefit of production development.[33,34]

An inverted telephoto-type wide-angle lens system capable of coverages up to 160° for use in scoring cameras was developed by the Douglas Aircraft Co. and the Wollensak Optical Co. Two versions of this system have been developed, one for 16mm cameras and one for 35mm cameras. While these lenses are not corrected to the degree required for theater-type motion-picture photography, they are entirely adequate for their intended application.[35] It is reported that a 165° taking lens has also been developed for use with the Todd-AO process, shooting on 65-mm film.

16 mm Stereoscopic. 16 mm stereo photography found increased use in the commercial and amateur fields. Bolex, Nord and Elgeet developed taking and projection lenses. Included in the group of equipment released by Elgeet, for example, were the taking and projection lenses, viewfinder, screen and spectacles. The 13-mm *f*/2.8 lens fits standard 16mm "C" mount cameras, and a pair of *f*/1.6 lenses will fit standard 16mm projectors.

CinemaScope: 35mm. The CinemaScope process, which is described in a separate section, required compressing optics on the cameras and expanding optics on the projectors. Numerous companies produced anamorphic cylindrical lenses, most of which behave like a reversed Galilean telescope in the horizontal meridian, halving the focal length of the objective and doubling the field coverage. In the vertical meridian the cylindrical attachment has no power, hence has no effect upon the focal length.[36, 37] Other companies that developed expansion-compression lenses were the Simpson Optical Mfg. Co. through the Vistarama Corp., Goerz American, Shiga Bros. of Japan, Oude Delft Optical Industries in Delft, Holland, and others. The Delrama optical system for anamorphic projection built by Oude Delft uses two mirrors instead of lenses and is reported to correct the "hollow" horizon and "leaning" skyscraper effects noted with cylindrical projection-lens systems. Taylor, Taylor & Hobson are manufacturing prismatic types as well as cylindrical refractive anamorphic projection lenses. A variable expansion-compression anamorphotic-ratio, prism-type optical attachment for taking and projection is under development by the Tushinsky Bros. The Shiga Bros. are reported to have developed an anamorphic camera lens with a pickup angle of 135° when used with a regular 25-mm lens on a 35mm camera.

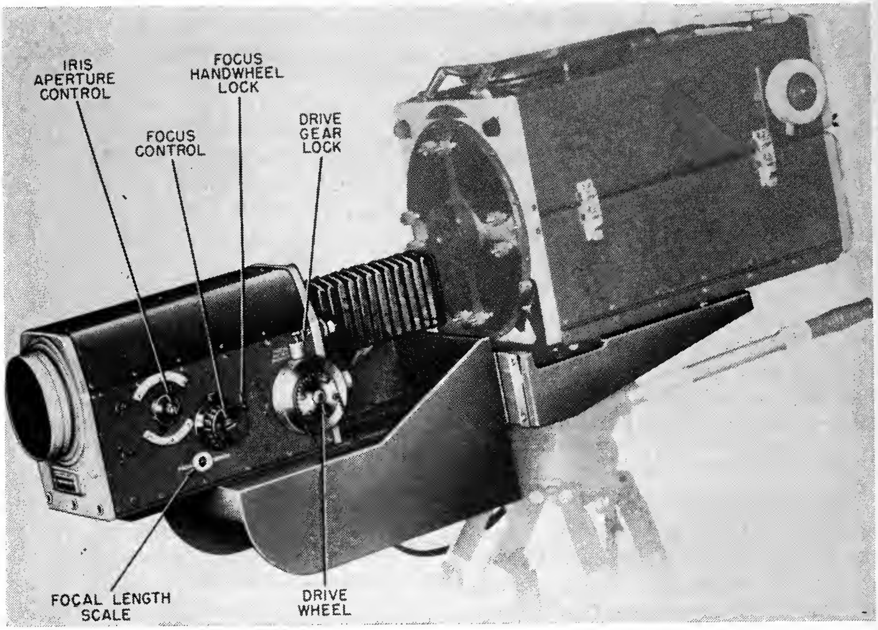

Fig. 10. The GPL-Watson Vari-Focal Lens PA-861.

CinemaScope: 16mm. The rapid acceptance of the 35mm CinemaScope system interested at least two companies, Bell & Howell and Vistarama, to the extent that versions of the larger-frame systems were introduced for the 16mm market. Bell & Howell has a projection lens for the 35mm Fox CinemaScope theater projection[38] as well as a taking and projection unit for the 16mm version. The Vistarama Corp. lenses, manufactured by the Simpson Optical Mfg. Co., are usable for both film sizes.[39]

Zoom Lenses. M-G-M announced and demonstrated the Expansa projection lens which is a variable-focal-length lens designed for theater use. With this lens the picture can be fitted in width and height to meet installation requirements and the focal length can be changed while the film is running to vary the size of the projected picture.

Zoomar Corp. announced the introduction of the Zoomar 16 for the 16mm camera. The lever-operated lens and coupled rangefinder have been designed for a focal range of from 1 to 3 in. at a maximum aperture of $f/2.8$.[40]

Taylor, Taylor & Hobson developed the Varotal zoom lens for use with television cameras, particularly for extreme, long shots of the Coronation.

The GPL-Watson Vari-Focal lens, Model PA-861 (Fig. 10), is a zoom-type camera lens for use in conjunction with television or 35mm motion-picture cameras. Focal ranges of 3 to 15 in. and 6 to 30 in. are available, by a replacement of the rear lens element. The focal-length change can be made continuously in controlled intervals varying from 2 to 30 sec.

Miscellaneous. Kern-Paillard introduced their Kern-Yvar-Filten 12.5-mm $f/2.8$ lens for 8mm cameras. This lens is unusual in mechanical construction in hat four filters mounted on a turret nside the lens mount are an integral ɔart of the unit. The filters included ıre yellow, red, daylight conversion and kylight.

Cameras

Data on CinemaScope, VistaVision, 3-D, Todd-AO, 16mm professional and cameras for television are described ınder their representative sections. In ıddition, Mitchell Camera Corp. developed an improved "follow focus attachment" for professional studio photography. It permits NC, standard and 16mm Mitchell cameras to be used for rapid changes of focus with full control of picture framing and lens focusing even at close critical distances.

The 35mm Arriflex was made available in a blimp and with an improved-type gyro-tripod head. Both the 35mm and 16mm Arriflex cameras are now equipped with optical bench-type attachments (Fig. 11) for the use of long-focal-length lenses. An interesting new micro-stop-motion device for 16mm cameras was announced by Werkstatt fuer Feinmechanik of Berlin.

16mm Projection

A new 16mm projector with a tungsten source is now equipped with a shutter which shifts from three interruptions per frame for operation at silent speed to two interruptions per frame at 24 frames/sec to gain light output. Philips[41] announced a new 16mm projector, Type EL-5000 with a 60° pulldown, increasing the light output from a conventional 50% to 67%.

New Color and Black-and-White Films

Eastman introduced their Type 5248 Color Negative Film, Type 5382 Color Print Film and Type 5245 Color Internegative. These films, together with Type 5216, Panchromatic Separation Film, already available, filled all requirements for color motion-picture production including special effects.[42,43] The

Fig. 11. The 35mm Arriflex camera.

35mm Color Negative incorporated coupler multilayer-type film which is developed to a negative dye image. Some of the couplers are themselves colored and produce color-corrected images. The film is balanced for 3200 K incandescent illumination with ASA exposure index of 25. The Color Print Film is an incorporated coupler multilayer-type film for use on suitably modified continuous contact motion-picture prints, or from color separation negatives on registering prints. The Color Internegative is a 35mm incorporated coupler multilayer-type film containing colored couplers which result in color-corrected images.

Ansco introduced their Type A-44 high-speed tungsten balanced color negative film with an exposure index of 25. Fifteen feature pictures were photographed with this new Ansco film during 1953. Du Pont introduced two new fine-grain 16mm films, the Rapid Reversal Pan Type 930 and High Speed Rapid Reversal Pan Type 931. These films permit rapid processing and have superhardened emulsions which permit the use of elevated processing temperatures. Both of these films can be used as negatives or with reversal processing.

In England, the integral tripack Ferrania Colour, Gevacolor and Eastman Colour films have been much more widely used. The Ilford Company brought out a new black-and-white Type HPS panchromatic negative with a daylight speed of 400 Weston and a tungsten speed of 300 Weston. It has provided small-grain size and appears to be a great advancement in emulsion manufacture.

The papers reported under references 44 through 54 cover many interesting developments in the use of color and black-and-white films.

Color Photographic Systems

Eastman color negative and positive 35mm films were extensively used in processing laboratories during 1953, The following laboratories were handling these films: Ace Laboratories, New York; Alexander Film Laboratories, Colorado Springs; Color Corp. of America, Burbank; Consolidated Film Industries, Hollywood and Fort Lee; Deluxe Laboratories, New York and Hollywood; Lakeside Laboratories, Gary; M-G-M Laboratory, Hollywood; Pathé Laboratories, New York and Hollywood; Technicolor Motion Picture Laboratory, Hollywood; Tri-Art Laboratories, New York; and Warner Brothers Laboratory, Hollywood.

Eastman 16mm color positive film was being used by Pathé Laboratories in New York to make reduction prints from 35mm Eastman color negative. Most laboratories were using subtractive printing methods, although the trend toward additive printing became pronounced.

Ansco color negative and positive films in 35mm were being processed by the following laboratories: Consolidated Film Industries, Fort Lee; Houston Colorfilm Laboratories, Burbank; M-G-M Laboratory, Hollywood. Ansco color film in 16mm positive was being handled at Consolidated Film Industries, Fort Lee. Du Pont 35mm color positive film was being processed by Consolidated Film Industries in Hollywood and Fort Lee.

Technicolor Motion Picture Corporation supplied 35mm and 16mm prints made by the imbibition transfer process from negatives prepared in three-strip, Eastman color, Ansco color, Kodachrome and successive exposure. Color Corp. of America prepared duplitized 35mm and 16mm prints in two- and three-color from bipack negatives and Eastman color negatives.

Film-Handling Equipment

The use of magnetic film for editing purposes increased steadily throughout the year both for theatrical and television use. The average film editor accepts magnetic "dailies" and uses them with a greater freedom of operation than ever before existed on photographic film.

The Westrex Editer film editing machine was introduced to the industry in 1953.[55] It can handle both standard and the new small-hole perforated 35mm films, film strips, motion-picture films, magnetic or photographic sound films (single or multiple), composite release prints, and for the first time makes possible the "projection viewing" of an enlarged image on a wall or screen without extra attachments.

A new editing machine, Type Record, has also been built by Union of Berlin for optical and magnetic soundtracks with built-in differential gears for film displacement and loop changes.

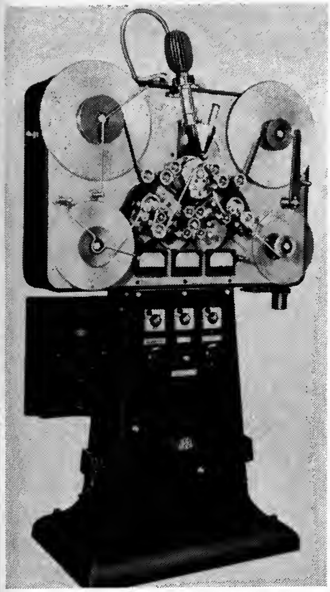

Fig. 12. Arnold & Richter 35mm to 16mm optical reduction printer.

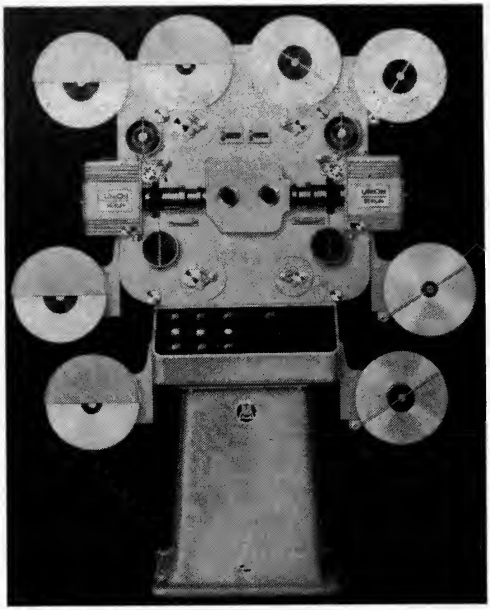

Fig. 13. Union "Optima" 35mm to 16mm reduction printer.

Arnold & Richter of Munich, Germany, have brought out an improved 35mm to 16mm optical reduction printer (Fig. 12).[56] The new "Multicolor 1" registration printer for color separation negatives, operating at 20 frames/sec, has been brought out by Union of Berlin. Union has also made a 35mm to 16mm optical reduction printer called the Optima, which uses an improved registration-pin system (Fig. 13). A new daylight developing machine, Type UEM, with sprocketless rollers, is available from Union, Berlin, while the Type 351-V for color processing has been built in separate sections for installation as space permits. Arnold & Richter[56] have brought out a 16mm reversal film developing machine with automatic temperature and speed controls.

The quality obtained in England in blowing up 16mm original Kodachrome to 35mm for the *Conquest of Everest* is renewing interest in this process for difficult location situations.

Motion-Picture and Television Stage Lighting

With practically all color photography now being made with tungsten light sources, the 10-kw incandescent tungsten lamp has found much wider use. Some 1400 lamp housings for this bulb have been adapted from other incandescent or arc housings. Mole-Richardson introduced the 10-kw Tenner, Type 416 incandescent lamp and a 5-kw flood for tungsten-lit color photography. Newly designed, lighter-weight Junior, Baby and Single and Double Broads, and Skylite flood also came into service. Various new "skypan" types of lighting units have come into use for overall illumination with considerable use being found for the 1-kw silver bowl reflector lamp. Higher levels of stage illumination are being used with 3-D and anamorphic lens systems.

To increase the life of C.P. lamps, the British Film Producers Association Lighting Committee is encouraging the use of 3250 K lamps. Studies are being made of this proposal in cooperation with Kodak, Gevaert and Technicolor.

An interesting new arc lamp using three carbons at 180 amp was developed by Arnold & Richter of Munich, Germany. A motionless arc and tailflame are basic advantages of this new design.

The Century Lighting Co. has done considerable work with remote-controlled incandescent lamps for television stage lighting. The facilities include remote control of intensity without change of color temperature or distribution pattern, an important feature for the future of the lighting of color television. Remote-controlled pan and tilt and elevation are also incorporated in these units, together with the necessary simplified operator control pedestals.

Set Construction

A number of plastics and allied materials[57,58] found application in set construction and the fabrication of props and statuary. One studio[59,60] is now using Fiberglas-reinforced polyester resins as a replacement for casting with plaster. Weight is reduced and mechanical strength increased which many times justifies the higher cost of the plastic material.

Emulsion paints of the polystyrene and styrene copolymer types are finding use in interior applications, while polyvinyl acetate and polyacrylic coating formulations are finding some use for outdoor applications. For making imitation metallic props, the Motion Picture Research Council developed a cold-spray metal composition which can be buffed to give a striking metallic luster. Salvage of worn-out electrical cables is being effected where the old cable is stripped of its worn insulation and drawn into new extruded neoprene jackets, using a simple vacuum process. The lubricant which is used changes at a later time into an adhesive or friction promoter between cable core and neoprene jacket.

Measuring Instruments

A new photoelectric Brightness Spot Meter[61] was developed by the Photo Research Corp. for the measurement of brightness for small areas. This instrument is useful for both photography and the checking of screen illumination. Agfa brought out a new-type logarithmic-scale exposure meter called the Lucimeter intended for professional use in studios.

High-Speed Photography

There was a marked increase in the field of high-speed photography during 1953. The bibliography in this field is now quite complete: 466 references are included in the new book *High-Speed Photography* by George A. Jones[62]; 581 references were published in the January 1951 issue of the *Journal;* 207 additional references[63] were published in December 1953; and 36 references are included as a part of this report. Short-duration electrical spark methods were described by Chesterman,[64] Fayolle and Naslin,[65] and Schardin.[66] Courtney-Pratt[67] described a method for dissecting a picture into small elements using a plate embossed with many small lenses. This paper lists 99 references.

New commercial-type equipment described during the year includes: a full-frame 35mm Fastax camera with 500-ft film capacity operating up to 2500 frames/sec[68]; a 70mm camera taking 25 pictures/sec, each $2\frac{1}{4} \times 5$ in., or 50 pictures/sec, each $2\frac{1}{4} \times 2\frac{1}{2}$ in.[69]; a 70mm X-ray motion-picture camera providing 15 frames/sec, each $2\frac{1}{4} \times 2$ in.[70]; a 70mm intermittent-action, pin-registered camera providing up to 450 frames/sec, each $\frac{1}{5} \times 2\frac{1}{2}$ in.[71]; and wide-angle optics used on high-speed motion-picture cameras to provide a field of view up to 160°.[35]

Southard[72] describes three methods used in recording the images of both 4-in. and 80-in. lenses on one roll of film so that a single radar boresight tracking camera can obtain a wide field of view during early stages of a missile's flight and a large missile image during later portions of flight.

Edgerton and Germeshausen[73] report refinement of a previously described[74] magnetooptic shutter which permits reduction of exposure time from 4 μsec to 1 μsec. This shutter has been used extensively at the Ballistic Research Laboratory, Aberdeen Proving Ground in the study of high-velocity shock waves and flame fronts.

Lipton and Saffer[75] describe extensive modifications that have been made in Askania cinetheodolites by Aberdeen Proving Ground and the Naval Gun Factory. The new instruments incorporate improved bearings, data circles and mount components; a camera operating synchronously up to 64 frames/sec as contrasted to the present top rate of 4 frames/sec; 500-ft film capacity and telescopic optical systems of varying focal lengths up to 180 in.

A valuable analysis of glow lamps used for high-speed camera timing purposes is provided by Ferree,[76] while Erickson[77] gives a general description of circuit requirements to provide timing marks in the range from 2000 to 8000 frames/sec. He also discusses increases in firing potential required when operating the NE-51 neon bulb in total darkness.

Bondelid[78] describes an improved version of a powered camera tracking mount previously described[79] as used in ballistic free-flight instrumentation. The mount carries 16mm and 35mm normal and high-speed motion-picture cameras photographing through new 24-in. and 48-in. *f*/8 refractor lenses which resolve about 200 lines/mm on their optical axes.

Sensitometry of short exposures was discussed by Castle and Webb[80] and by Tupper,[81] indicating continued interest in reciprocity-law failure effects in short-duration exposures.

Numerous applications of high-speed photography were cited during 1953. Photography of arcs and flames emitting high-intensity light was described by Stubbs, Rothschild and Moen[82] and by Stern and Foster.[83] Use of high-speed photography in rocket and jet propulsion studies was described by Stratton and Stehling[84] and by Berman and Scharres.[85] The latter paper discusses several types of American and European high-speed cameras, including the new Warrick streak cameras which transport 35mm film up to 125 ft/sec; the Acmade full-frame 35mm camera holding 200 ft of film and operating up to 2000 frames/sec; the M.G.D. 80-lens cameras taking a total of 750 pictures at rates up to 100,000/sec; and British developments in the image converter tube field.

Photography of high-voltage electrical arcs by the Bonneville Power Administration was described by Harrington and Ramberg[86]; Blunt[87] described high-speed photographic instrumentation of large underground explosions conducted in Utah; Brown[88] outlined use of high-speed flash in securing records of aerodynamic patterns in a wind tunnel using smoke trails; and Johnson[89] described high-speed photographic recording in the textile and black-powder wrapping fields. Waddell[90] outlined general procedures in the photography of motion; while Wilkinson and Romig[91] explained the simultaneous use of several high-speed cameras to cover the time intervals between pictures provided by any one camera.

A thorough introduction to the schlieren, shadowgraph, and interferometer techniques is provided by Barnes,[92] who incorporates a bibliography of 219 references in his paper.

Clason[93] explained the use of conventional photoflash bulbs to illuminate a gun-fired projectile for photography at 6000 frames/sec in tests conducted by NACA. The use of high-intensity, high-speed repetitive flash illumination is described by Fristrom.[94]

An image-transport disc camera operating at 100,000 frames/sec and yielding 8mm motion pictures in a form suitable for normal projection is described by Miller and Scharf.[95] Other forms of ultra-high-speed photography applied to the study of explosions are well outlined by Sultanoff,[96] citing examples of work done at Aberdeen Proving Ground using streak, single-exposure, and high-speed motion-picture cameras.

Armed Services

The United States Air Force has made extensive use of kinescope recordings and television for training-film purposes. Approximately 125 kinescope productions were made during 1953, utilizing more than 170,000 ft of film. Television was also used by the Air Defense Command in televising weather information to pilots.

The Signal Corps is evaluating the applicability of television for use by the Army. The Human Resources Research Office of George Washington University is making the evaluations. The Signal Corps Mobile Television System is conducting a series of studies involving training and tactical applications of television. The Signal Corps has also a tactical television system using miniaturized equipment mounted in tactical vehicles and airborne equipment.

The United States Navy is conducting tests of underwater television kinescope recordings while the Bureau of Ships has developed underwater television camera equipment for such studies. Underwater illumination is furnished by specially developed mercury and xenon arc sources. The Naval Photographic Center has developed improved kinescope recording equipment and techniques for these applications. Rapid and unpredictable changes in subject brightness and contrast make desirable the use of film of greater latitude and higher speed than commonly used.

A high-speed facsimile system which transmits and receives at the rate of ten letter-size pages per minute has been designed by the Navy Bureau of Ships and developed by the Radio Corp. of America, in conjunction with the Haloid Corp. The copy to be transmitted is picked up by a flying-spot scanner, and the received copy is reproduced by the automatic continuous xerographic process. Rapid processing machines for aerial roll film and paper, for 70mm, 35mm and 16mm film are now in production. Naval photographic processing is being changed over to continuous rapid machine processing.

The Army Pictorial Center has developed a technique of recording on loops of magnetic film which has greatly simplified the "lip synchronization" of foreign languages to Army training films (see the paper on this subject soon to be published in the *Journal*). The Naval Ordnance Test Station has developed a versatile tracking camera which is mounted as an independent unit, supplying its own power, and capable of negotiating heavy sand. A new tracking telescope type of optical recording instrument has been produced at the White Sands Proving Ground by the Army for missile programs. Its flexibility permits the use of different cameras and optical systems, and its use as a cinetheodolite of moderate precision.

Color Television

The NTSC compatible color television system made great development in 1953 under the continued direction of the various panels of the National Television System Committee.

An NTSC color television demonstration was presented at the Hotel Waldorf-Astoria, New York City, in October 1953, where 13 color television receivers, as produced in the United States, were placed in operation. The color pictures were viewed by many engineers, the press, industry leaders and others who are interested in the color television development.

Late in 1953 the FCC approved the NTSC method, reversing its earlier approval of the CBS field-sequential system.

NBC has been transmitting several of its regular shows in color. The transmissions have been picked up with excellent quality on standard black-and-white receivers. The RCA color cameras used were equipped with three image-orthicon tubes, one for each of the primary colors. A one-tube camera is under development by RCA. CBS has developed a color camera which uses a single tube operating on a field-sequential basis with a rotating filter-wheel behind the lens. The signal then goes to a "chromacoder," a device which translates the signal into the NTSC standard.

One of the techniques making up the NTSC system is described in the FCC Report and Order as follows: "(It) relates to the demonstrated fact that the eye is much less sensitive to changes in hue and saturation in small areas than it is to changes in brightness. The corollary is that as the size of the viewed object is reduced, the eye becomes progressively color-blind so that ability to distinguish hue deteriorates. It follows that the color components of a picture can be transmitted over a narrow band of frequencies since resolution of fine detail is a function of bandwidth. In the NTSC system faithful colors are transmitted over a 0.06-mc bandwidth while the monochrome or luminance signal is transmitted over a 4.2-mc bandwidth. In between is a twilight zone where adulterated colors are transmitted. Thus, faithful colors appear in the coarse areas of the picture, adulterated colors in the medium-fine detail and only monochrome in the finest detail of the picture. The saving of frequencies resulting from the use of this technique is obtained at a cost in terms of the adverse impact on picture quality, but as indicated below, the overall result meets minimum standards of acceptability."

Studio experience in television color program production indicates that lighting will be simplified over what it has been heretofore. Lower color temperatures will be needed — 2900 to 3200 K is expected to be standard. This means that color television can use standard tungsten light sources and will not require the radical changes in studio lighting which were necessary when Technicolor, for example, entered the motion-picture studio. Levels will, of course, be considerably above those required for black-and-white television.

"Electronic Photography" in Color and Black-and-White on Magnetic Tape

Recording of television pictures on magnetic tape in color and black-and-white was demonstrated by RCA on December 1, 1953.[97] Thin, half-inch wide, magnetic-coated plastic tape, running at 30 ft/sec, was used for the color demonstration.

Seventeen-inch diameter reels recorded 4 min of television program. Five parallel recordings were made on the single tape, one for each of the red, green and blue primary color signals, the fourth for the synchronizing signal and the fifth for sound. A $\frac{1}{4}$-in. wide tape is sufficient for black-and-white recording.

Telemeter

The Telemeter system of pay-as-you-see television, developed by the International Telemeter Corp., started commercial operation in Palm Springs, Calif., on November 28, 1953. A special Telemeter channel, carrying the best in motion-picture entertainment and sports, was added to the free Los Angeles television distributed by the Palm Springs community system.

In building the Palm Springs community television system, ITC was led to develop its own line of broad-band VHF amplifiers and accessory community television equipment, since the equipment then commercially available was unable to do an adequate job. This community television equipment developed by ITC was marketed under the name of Ampli-Vision in the latter part of 1953.

Kinescope Recording

On the West Coast, kinescope recording increased in amount for programs delayed three hours in presentation.[98] 35mm kinescope recording has also increased in New York for pre-recorded network shows which are reproduced from the kinescope negative.

Improved black-and-white kinescope recordings are being obtained by using ultraviolet light produced by a special phosphor and recorded on a specially prepared photographic emulsion. Some stations are changing from 5-in. to 10-in. recording kinescopes to obtain a greater ratio of image size to phosphor grain size and reduce eyestrain. Gamma-correction circuits are being used to render more detail in face tones and black areas.

A new field for kinescope recording is developing as colleges and universities develop plans for an educational film network to facilitate the interchange of program material.

Film Production for Television

The iconoscope has continued to be the "work-horse" for motion-picture film reproduction, although a few stations use the image orthicon for this purpose.[99] There have been, however, several notable developments in electrical and mechanical design which indicate that the flying-spot scanner and the vidicon tube will soon be widely used for film reproduction and that continuous-motion projectors may also play an important part in color television film reproduction.

The Philco Model FSS-5 Television Film Scanner[100] is a 35mm continuous-motion projector mechanism employing a 24-faced rotating prism and a flying-spot scanning system. It may be used for monochrome television, or by the addition of a "color head" it becomes suitable for use with color television. A shrinkage compensator permits adjustment for films of varying pitch.

The Du Mont Multiscanner[101] is a versatile and ingenious device employing a centrally positioned flying-spot cathode-ray tube whose light output is optically multiplexed to two motion-picture film handling machines and two opaque slide or baloptican picture holders. These four picture sources can simultaneously produce independent television images by means of their respective multiplier phototubes, all of which receive light from the same flying-spot source. A special 16mm film handling machine known as the "cinecon" has been designed specifically for use with this system. It is a continuous-motion machine resembling in external appearance a conventional projector, but employing a 24-faced rotating prism and having, in place of the lamphouse, a multiplier phototube which produces the monochrome electronic picture image.

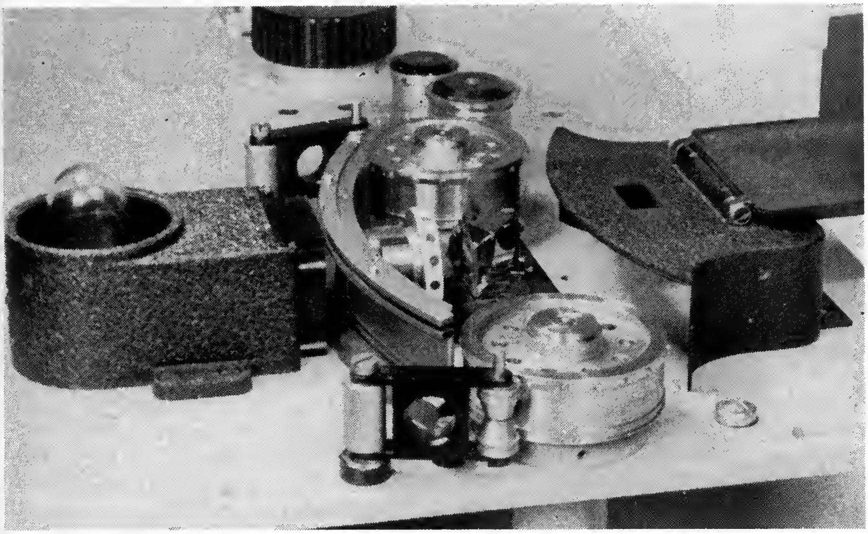

Fig. 14. Askania 16mm television projector of the nonintermittent type with optical compensation by means of a rotating prism.

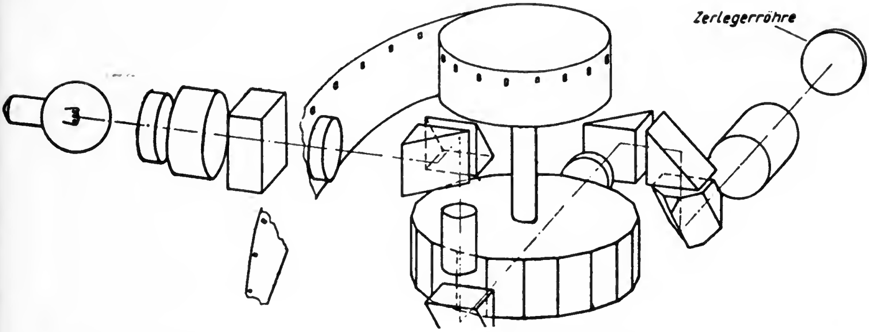

Fig. 15. Schematic of the Askania continuous-motion television projector.

Motorola, Inc., has devised a continuous all-electronic scanner for 16mm color motion-picture film which operates on a different principle.[102] No rotating prisms or mirrors are used. A "jump-scan" technique is employed wherein the vertical deflection of the cathode-ray tube forming the flying-spot light source is shifted by an amount equal and opposite to the film travel, thereby electrically immobilizing any given spot on the film. Since a ratio of 2 to 5 is required to convert 24 film frames to 60 television fields per second, one film frame will receive 3 jump-scans, while the next film frame will receive 2 jump-scans, thus making a total of 5 jump-scans for 2 film frames. The flying-spot beam then returns to its original position on the face of the cathode-ray tube to begin another cycle. Servomechanisms are used to remove picture instability. Thyratron tubes triggered by television vertical synchronizing pulses provide the nonsynchronous power for the main drive motor. Dichroic mirrors divert the flying-spot light beam to the respective photomultiplier tubes for color reproduction.

An important development in the field of intermittent projectors was the 16mm fast pulldown projector developed by RCA for use in color television.[103] By means of a three-pointed star Geneva coupled in series with a shuttle-and-claw type intermittent through a 3-to-1 gear train, it was possible to achieve film pulldown during television blanking time, a period about 1250 μsec in duration. This extremely fast pulldown permitted the use of a flying-spot scanning system utilizing a color diplexer.

16mm Projector for Television

Three new 16mm projectors for full-storage operation were described in the *Journal*. The General Electric projector uses a gas-discharge tube[104] while the new RCA[105] and Eastman Kodak[106] projectors use a tungsten source.

16mm Television Film Equipment

The Ernst Leitz Co. in Wetzlar, Germany, further improved their 16mm professional projector, Model Leitz G-1, for television use. A Geneva movement with steadiness better than 0.1% is reported. A synchronized motor with special optics and still-projection equipment permit the projector to cover a variety of pickup tubes and to be used for straight projection. A $2\frac{1}{2}$-hr continuous running time with 4500-ft magazines is reported with top film reel running vertically.

Askania[107] of Berlin has brought out a 16mm television projector of the non-intermittent type with optical compensation by means of a rotating prism (Figs. 14, 15).

Television Rear Projection

Television studio rear projection reached a new peak with the NBC production of *Richard II* when a screen 15 ft high and 60 ft long was used. This was illuminated by two 90-amp arc slide projectors using 4 × 5 in. slides made on a new heat-resistant glass. NBC has put a new type of screen into use made of blue latex rubber which has better diffusing quality than any before in use. It is said that one can stand at a 45° angle to this screen and see no noticeable difference in illumination from that observed at the perpendicular. This means less fall-off of illumination around the sides of the screen and a greater flexibility in the use of angle shots from widely spaced camera positions.

Television Studio Techniques

Television manufacturers came out last year with several very small television cameras — so small as to be almost in the size and weight class of 16mm movie cameras. Although this equipment was intended for industrial use, many broadcasters were immediately interested because of the exceedingly low cost. By year's end, over fifty broadcasting stations were using these cameras built around RCA's vidicon tube.

RCA put a 4-lb vidicon camera on the market which retails for under a thousand dollars. More useful for the broadcaster was the Dage camera (manufactured by Dage in Indianapolis, and also sold by Du Mont as the "tel-eye"). This camera, the size of a brief case, is a complete camera chain in itself, into which have been incorporated camera and viewfinder, camera control unit, power supply and synchronizing pulse generator. It puts out an rf signal which can be tuned to one of several standard television channels and fed directly to the antenna terminals of any standard receiver. The General Precision Laboratory staticon, built around the English staticon tube, is also competing in this field.

Less sensitive than the image orthicon, the vidicon is not capable of the same resolution and picture quality, but on the other hand does not exhibit halo, streaking and other image-orthicon faults, and does not burn in a picture if left on a static scene. This has been particularly interesting to broadcasters since it means the camera can be left unattended.

The vidicon tube has also been incorporated into a new and improved film-pickup camera now offered by RCA. It is expected to replace the iconoscope tube for film pickup and rival the flying-spot scanner.

The German Television Society in Darmstadt has developed a very small light-weight image-orthicon tube.

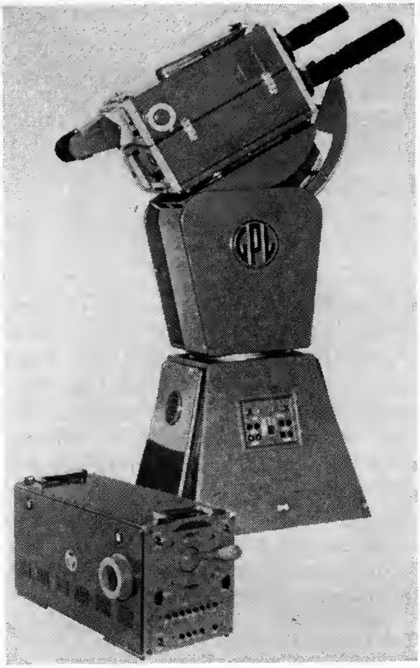

Fig. 16. The GPL Model PA-870 television camera pedestal showing remote-control components.

Television Equipment

General Precision Laboratory developed a television camera pedestal with remote control of pan and tilt movement (Fig. 16). Rate and position control of both pan and tilt as well as six preset pan and tilt positions are provided. Pan through 280° and tilt through 63° are provided. With suitable remote focus and lens-change facilities on the camera, the choice of lens and focus can be preset. The pedestal can be remote-controlled.

35mm television background and film-chain projector Models PA-200 and PA-201: Recent experience in television film systems indicates that quality improvement is obtained by operating vidicons and image orthicons with the longest available light pulse. The GPL 35mm film-chain projector has a 2:3 intermittent which is sufficiently fast to permit the use of a 40% open shutter. When equipped with an arc lamp, this machine is useful for television background projection and when equipped with smaller light sources, it is suitable for film-chain applications with any of the commonly used pickup tubes. Current experiments show the same high-quality performance with film chains for NTSC color transmission.

Television Broadcasting Stations

Television broadcasting in the United States made tremendous strides in 1953. There were 250 additional television stations added before the end of 1953, some of these being equipped for operation in the 470- to 890-mc UHF region. Four of the new stations are educational outlets.

During the year new 25-kw and 50-kw VHF television transmitters were developed, and there were new achievements in antenna design as well as progress in the field of camera and studio equipment.

Television Picture Tubes

There was some improvement in the types of cathode-ray tubes in general use during 1953. Generally, there was some improvement in more careful alignment of tube structures, in the provision of greater resolution, reduced beam "spot size," and the greater overall use of the screen surface. During the first eleven months of 1953, 9,194,851 cathode-ray tubes were sold in this country to owners of television receivers.

It was felt that the future use of television picture tubes will increase in the United States because of the now growing demand for replacement tubes.

Television Receivers

There were 5,600,423 television receivers sold through retail outlets in the United States in 1953. There was considerable improvement in these receivers because of the use of advanced circuitry, synchronization, improved picture definition, improvement in noise figure, etc. The 21-in. cathode-ray tube continued to be used this year as the outstanding picture-tube size accepted.

Some progress was made during the year in the production of UHF converters, receivers, antennas and tuners. These were designed for use in the new 470- to 890-mc/sec UHF broadcast band.

Television in Schools

The installation of studio equipment in schools and universities has proceeded at a rapid rate, and today approximately 20 schools are equipped to teach television with standard broadcasting equipment. Nearly a hundred schools of higher education have courses in television program production listed in their curricula. Many of the schools which have campus studios originate regular programs which are relayed to local television stations for broadcast.

Three new educational television stations went on the air during the last year, and 29 more have construction permits and are expected to be ready for broadcasting soon. Forty-five noncommercial applications have been filed.

Miscellaneous Television

A special device for the remote television transmission of surgical operations was developed in Germany, using a specially designed ring-type lighting equipment.[108] The German Television Society in Darmstadt has proposed a means of transmitting television pictures in 3-D using Polaroid foils.[109]

Conclusion

The above represents an incomplete but significant review of the progress during 1953 in motion-picture and television technology. The chairman of the committee wishes to express his thanks to the committee for their valuable contributions and to the following for special reports:

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Temperature-Sensitive Phosphors for the Evaluation of Air Jets Designed to Cool Motion-Picture Film

By F. J. KOLB, JR., and F. URBACH

In the projection of motion-picture film at high intensities for maximum screen illumination, it is sometimes desirable to cool the film and control its position with a blast of high velocity air. This paper presents a method for evaluating the design, placement, and operation of the jet which provides the cooling air. The heart of the method is the fact that the brightness of certain phosphors depends strongly on temperature. Such phosphors provide an immediate visual indication of the temperature distribution over the film face. Examples of several air flow patterns revealed by the use of phosphors are discussed. Test results obtained by projection of film are compared with predictions.

DEMANDS for higher light output from motion-picture projectors to supply the requirements of both the outdoor theaters and the larger indoor theaters, have emphasized the existence of limiting values of radiant flux beyond which film performance becomes unsatisfactory, and have focused attention upon means for increasing screen illumination without making additional demands upon the film. This situation has been reviewed more fully in a previous article[1] which discussed the behavior of motion-picture film under high radiant-flux densities, and considered several general approaches to the problem of keeping actual film temperatures below the critical threshold. This earlier paper pointed out that cooling the film in the aperture by streams of high-velocity air is one method of increasing the safe permissible maximum flux density, and therefore increasing total screen light.

In order to take advantage of air-cooling it is necessary to design jets which provide high-velocity air over the entire film surface exposed in the gate. It is the purpose of this paper to consider the problems of proper jet design, placement and operation.

Film in the aperture is able to lose some heat by radiation to cooler surroundings, by conduction to solid surfaces in direct contact with it, and by conduction into the air — which latter heat is carried away from the film sur-

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face by the air's convection currents. This convection cooling can be increased immensely by high-velocity jets, but their design is complicated by several restrictions. The jets must be entirely outside the cone of light illuminating the frame, they must not interefere with the essential elements of projector construction, they must cool an area not easily accessible and further surrounded by interfering shapes and objects, they must operate with as little noise as possible, and they must make reasonably efficient use of the air supplied. Determining whether the entire aperture is cooled satisfactorily or whether the most efficient cooling is being realized, requires the study of considerable amounts of film projected under varying conditions and examined carefully upon the screen. The time-consuming nature of this operation and the skill required in interpreting results have made it difficult to select the most promising jet designs from the multitude of possibilities that exist.

A Method of Solution

Design of air jets would be simplified greatly if the effects of changes could be assessed quickly and easily! A method for determining patterns of temperature distribution with the aid of temperature-sensitive phosphors, developed in the Kodak Research Laboratories,[4,5,6] was found to provide a suitable tool for a preliminary testing of air-jet designs. This method makes possible both visual observations of the effects of changes in design and photographic records of such patterns as are of most interest. By this procedure, the best nozzle designs and their best methods of operation can be established so that final evaluation of film performance need be made only on selected designs.

This method of jet evaluation was made possible by fundamental research on phosphors pursued diligently during the last decade and greatly stimulated by the military problems of the last war. As a by-product of that work a class of luminescent materials has been developed which shows a strong variation in visible emission* with temperature of the phosphor. The best of these materials — if excited to visible emission by ultraviolet radiation — show a degree of temperature dependence that makes them valuable indicators for determining the temperatures of surfaces to which the phosphors have been applied. Sensitivities can be increased so that a discernible difference can be shown easily for temperature changes as low as 1 C, or reduced manyfold for the study of temperature variations over a range of 100 C or more.

Applied to the engineering problem of determining proper jets for the air-cooling of motion-picture films, temperature-sensitive phosphors provide a ready evaluation and comprehensive understanding of the problem. The opportunities for visual appraisal of each change in design are especially important in making the method informative and time-saving.

Procedure

In order to complete a survey on the possibilities of cooling of film by high-velocity air a study of jet design was undertaken and an exploratory survey was made using temperature-sensitive phosphors. Two phases of the procedure for this survey are of interest because they illustrate proven methods of operation: the preparation of the phosphor and the development of suitable test apparatus.

The phosphors used in this investigation have been described and discussed from the point of view of their purely scientific and theoretical interest in several papers[2,3,6] and the application of such phosphors to the general problems of determining temperature distribution has been outlined.[4,5,7]

* Some phosphors in this class change the color of their emitted light with temperature, while others change their brightness only.

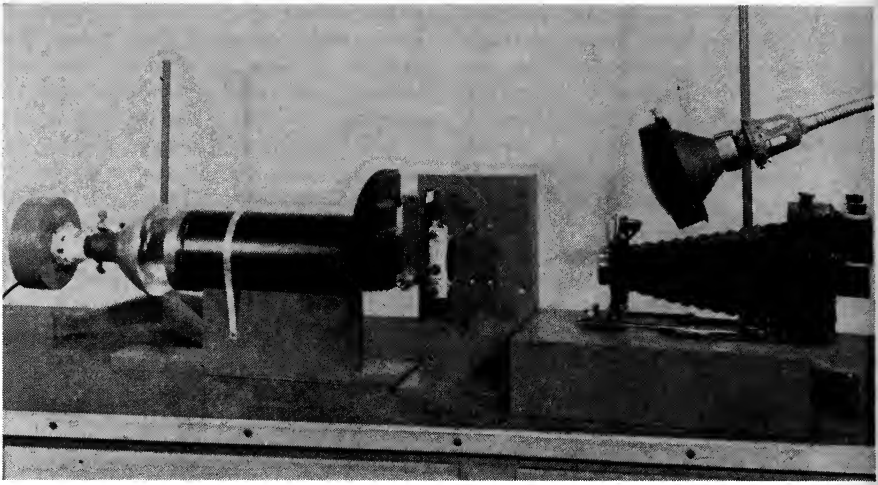

Fig. 1. Experimental setup for production and study of fluorescent patterns on air-cooled film.

The particular phosphors used in this investigation were zinc-cadmium sulfides activated by 400 parts per million (by weight) of silver together with three parts per million of nickel. With sufficiently intense ultraviolet excitation, these phosphors show a bright yellow emission whose intensity has a high temperature sensitivity between room temperature and about 250 F; a change in temperature of 1 C can produce a brightness change of up to 10% or 20%.

The finely divided phosphor was suspended in a nitrate lacquer, and spray-coated onto the base of a length of black film having an original density slightly over 3. In use the film was heated by the absorption of radiant energy in the black "image," while the fluorescence was examined from the opposite (base) side, screened from all ambient light. Film temperatures were maintained at approximately 230 F (approximately the maximum film temperature expected in some of the moderately large theater projectors) so that normal mechanisms of heat transfer from the film would prevail.

Obtaining suitable response from the phosphor requires a proper balance among (1) composition of the phosphor, (2) intensity of the ultraviolet excitation, (3) intensity of radiant flux supplying heat to the phosphor-coated film, and (4) efficiency of the cooling air flow operating to remove heat from the phosphor-coated film.

The response of these phosphors has been found to be a rather complicated function of the exciting ultraviolet intensity and of the temperature. Both the operating temperature range and the sensitivity of the phosphor depend upon this excitation; the useful temperature level is raised and the sensitivity decreased as the exciting illumination is increased.* Constant ultraviolet intensity was used throughout for convenience and simplification of the technique.

Final control of the phosphor indication was obtained by adjusting the film temperature to make the fluorescence pattern yield the most information. For

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* In some applications this dependence requires much attention to the problem of securing sufficiently even ultraviolet intensity over the whole phosphor area, but no such difficulty arises with an area of only 0.5 sq in. to illuminate!

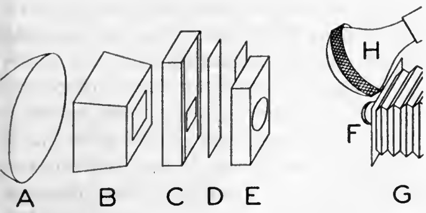


Fig. 2. Essential equipment of experimental setup shown opposite: (A) radiant energy source; (B) sight box and associated impediments to air flow; (C) film trap; (D) black film, coated with temperature-sensitive phosphor; (E) film-trap door; (F) ultraviolet-absorbing camera lens filter; (G) camera; and (H) ultraviolet light source.

example, a series of pictures at constant radiant flux but varying air flow from a given jet will show the change in film temperature resulting from the change in cooling, but any wide change will shift the fluorescent light so far toward high brightness or low brightness that the "tonal range" — the indication of temperature distribution — will be less extensive. If, on the other hand, the radiant flux heating the phosphor-coated film is changed with each change in air flow, it is possible to maintain at all flow rates a clear rendition of the detailed pattern of air flow at the expense of a ready comparison of film temperatures between flow rates. This simplified technique, therefore, allows either temperature level or distribution to be compared at will.

First interest in the design of air jets is usually in the detail of air flow and distribution. When all jets have been compared in this way, the better ones can then be compared at constant radiant flux to determine relative efficiencies of the jets.

Specific apparatus for the evaluation of air jets is shown in Fig. 1, and the components are identified in Fig. 2. While it is perfectly possible to use a complete projection mechanism, we found it more convenient to mount the film trap, baffles, fire shutter, etc, on a base plate duplicating the main frame casting, and to construct on this plate a nonoperating mock-up of the projector. The radiant flux was supplied by an incandescent lamp (a Photospot RSP-2 on variable voltage) located to give the proper energy distribution across the gate, and baffled so as not to contribute significantly to the general room illumination. The strip of black phosphor-coated 35mm film was held stationary in the gate. Ultraviolet excitation at 3650A was provided by a G. E. 100-w CH-4 projector spot lamp covered with a Corning No. 5874 filter and set about 15 in. from the phosphor-coated film, with the incident ultraviolet nearly normal to the film. A camera was set along the optic axis of the mock projector, to photograph the fluorescence pattern of the phosphor-coated film.

Uniform absorption was obtained over the entire frame by using a black strip of film — representative of very low-key photography and of the dense scenes that generally cause trouble first when film is overheated. The black, opaque frame together with the baffling of the incandescent lamp heating the film kept the incident light out of the room, and permitted convenient examination of the fluorescent image of the phosphor without the degradation of spill-light.

While the fluorescent pattern is visible with adequate contrast, a photograph taken without further precautions has its contrast greatly reduced by the actinic ultraviolet which floods the scene. Adequate photographs can be made only by equipping the camera with an ultraviolet-absorbing filter such as the Wratten No. 2B.

The mock projector as a first approximation has given useful results, even though there are obvious differences between film temperatures in the mock projector and film temperatures in an actual projector. This simplified apparatus used for convenience, however, comes closer to reproducing the distribution of maximum temperatures in the film than might at first be assumed. Of primary importance to the basic problem of higher screen illumination is this level and distribution of maximum temperature in the film. As shown previously[1] the best information available indicates that this maximum occurs in the emulsion close to the emulsion-base interface, that it occurs at the end of the projection cycle just as the pulldown blade is about to interrupt the light, and that the temperature rise is extremely rapid.

The basic difference between the test conditions obtained on the mock projector and those on an actual projector is the substitution of steady-state heat flow for transient-state flow. The transient flow in the actual projector leads to the following conditions[1]: (1) heat input by absorption of radiant energy in the photographic image is so rapid that conduction even through the thickness of the film is negligible and the temperature rise of the base surface is insignificant; (2) conduction sidewise and heat flow from hot, dense areas of the image to clear areas or to surrounding film out of the light beam must be negligible also, because of the even greater ratio of path length to crosssection; (3) significant heat loss by both convection and radiation must occur from the emulsion surface only, since that surface rises rapidly to a high temperature and remains the only high-temperature surface during the projection interval.

The steady-state equilibrium in the mock projector, on the other hand, will be seen to lead to the following conditions: (1) the heat input by absorption of radiant energy in the black film is again limited to the image surface, but there is time for heat to be conducted away through the film in all directions; (2) if there were no heat loss at all from the base surface, then this surface (where our temperature-indicating phosphor is located) would reach a temperature identical with the emulsion surface, but this situation is never reached exactly since both surfaces lose heat at approximately equal rates by radiation, and the phosphor surface loses some further heat by convection cooling in the "still air" surrounding the base side of the film; however, the convection heat-loss from the emulsion surface under forced air-cooling is so much greater than that from the base in "still air," and at the temperature levels employed so much greater than the radiation loss, that as a first approximation *the most significant heat loss* is from the emulsion surface; (3) in the steady state there is time for heat conduction parallel to the face of the film to areas outside the light beam; because of the extreme thinness of motion-picture film and the distributed heat input over the entire frame area this is important only at the very edge of the aperture where the temperature gradient increases.

As a result the temperature contour of the base surface of film in the mock projector becomes nearly identical with the temperature contour of the emulsion surface. Since it is on this base surface that our temperature-sensitive phosphor is located, the result is that temperature pattern made visible by the phosphor is nearly equivalent to that on the emulsion surface of the test film — and this in turn has been shown nearly equivalent to the temperature pattern of transient maxima in black film in an actual projector.

By arbitrary choice of the intensity of incident radiation whose absorption is responsible for the heating of the film, this emulsion-surface temperature (and subsequently the phosphor temperature) is made to approximate reasonable film temperatures in normal projection. Therefore the temperatures indicated in the steady-state mock projector bear a close relationship to the significant temperatures of film in an actual projector — the relationship becoming more direct as the air cooling becomes more efficient.

The general correctness of this reasoning is shown by our success in appraising jets. We have found that those which look best in the phosphor evaluation also perform best in actual tests with moving film in a standard projector, thus establishing our own confidence in the validity of the phosphor indications.

Interpretation of the phosphor patterns was semiquantitative in this work, although it can be qualitative or precisely quantitative as the need and justification arise.[5] Fluorescence patterns represented by Fig. 4 and those following were examined visually or photographed for record without the calibration necessary to establish actual temperatures from the photograph. Decisions on the relative efficiencies of air jets, on the best methods of adjustment, and on the adequacy of frame coverage can be made from the qualitative observations of temperature distributions. In a serious program to design and use air cooling of motion-picture films, such a qualitative program is adequate to guide the work, suggest equipment developments and modifications, and speed progress materially.

It would be difficult in practice but perfectly possible theoretically to apply some of these same techniques to actual film moving at projection speeds through a standard projector. Under these conditions of course it would be desirable to determine actual temperatures.

Results and Examples

The work on jet design reported here is illustrative only and does not attempt to develop the optimum jet for any specific projector. As discussed earlier, this optimum will depend on structural features of the particular projector; it will also depend on how much modification of existing equipment the designer is willing to undertake in those instances where a compromise must be sought between several purposes.

Introductory studies of the phosphor technique were made on the air jet shown in Fig. 3, which earlier work[1] had

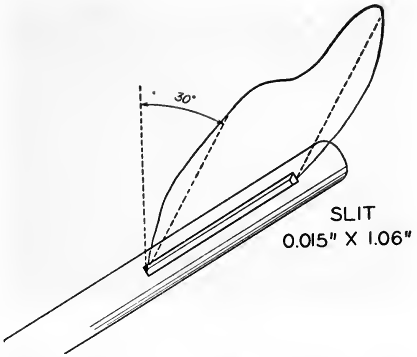


Fig. 3. Slit nozzle, showing slit dimensions and impingement angle.

shown to be reasonably efficient. This jet is a horizontal slit, directing a sheet of air upward and forward to hit the emulsion surface of the film near the horizontal centerline. Figures 4, 5 and 6 show the difference in the cooling pattern as the angle of the slit jet — and therefore both the angle of the air stream and its point of impact on the film — were varied.

Photographs of all phosphor patterns are positives: the lighter areas correspond to higher brightness (and lower temperature), the darker areas to lower brightness (and higher temperature). All these photographs are masked to show only the full-frame film area immediately in front of the projector aperture. The figures are right-side-up as viewed from the projection lens. The graininess visible in these photographs results from the granular nature of a spray coating of phosphor. This can be minimized further when necessary by more care in the preparation of phosphor coating. In these illustrations where the frame has been magnified several times it should be apparent that the grain pattern does not obscure the results.

In Figs. 4, 5 and 6 it will be seen that increasing the angle and lowering the line of impact moves the area of maximum cooling closer to the bottom frame-

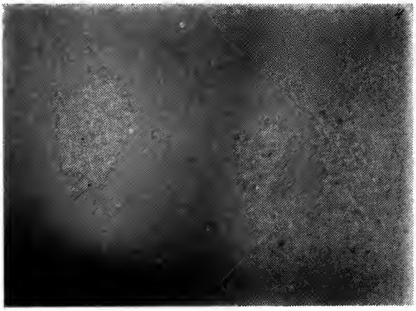


Figure 4

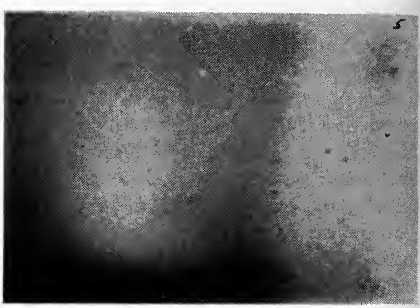


Figure 5

Figure 6

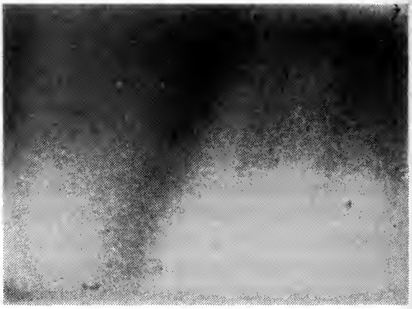


Figure 7

Figs. 4–7. Phosphor patterns: cooling pattern of slit nozzle, in impingement angle series, at 20° (Fig. 4), 30° (Fig. 5), 40° (Fig. 6), and 30° (Fig. 7). Figure 7 shows unnatural air flow resulting from removal of all structure around the gate but is otherwise comparable with Fig. 5.

line. Previous studies with film had shown an angle of 30° to be optimum for this particular jet and the phosphor patterns also show the best distribution for this setting.

Necessity for similitude between any mock projector that may be built for preliminary studies of cooling and the actual projector, can be shown by comparative phosphor patterns. Figures 4, 5 and 6 are made with care to duplicate exactly all the detail of the actual projector in the vicinity of the aperture. Figure 7, on the other hand, is comparable with Figure 5 except that the fire shutter, operating linkages, baffles, etc. that surround the aperture of an actual projector were removed from the mock projector. It is obvious that these elements — although not directly in the path of the air stream — modify the air flow away from the aperture and so change the resulting cooling. This is especially apparent from the reduced cooling in the upper right-hand corner (nontrack side) of the aperture.

Effect of air velocity on distribution is shown in Figs. 8, 9 and 10, taken at nozzle velocities of 240, 680, and 950 ft/sec respectively. These pictures were taken with the radiant flux heating the phosphor-coated film strip balanced to the air-cooling so that approximately constant detail appears on the phosphor.

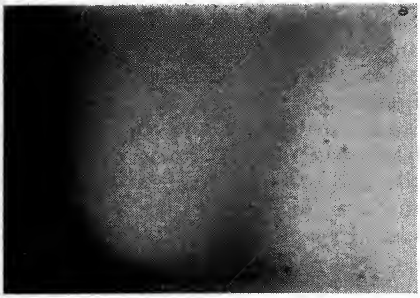


Figure 8

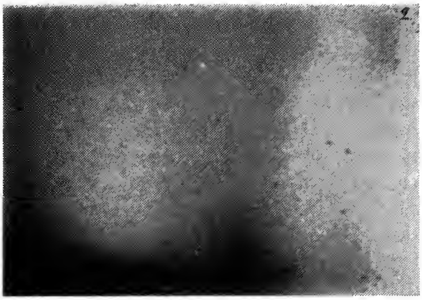


Figure 9

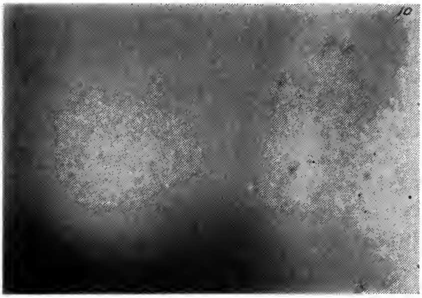


Figure 10

Figs. 8–10. Phosphor patterns: cooling pattern of slit nozzle, in air velocity series, at a jet velocity of 240 ft/sec (Fig. 8), 680 ft/sec (Fig. 9), and 950 ft/sec (Fig. 10).

The photographs show that there is remarkably little change in air pattern with velocity — a property which is very desirable for practical use, but which may not always be realized in a complex jet. The convention in these figures (as in the previous discussion of air-cooling)[1] is to report air velocities at the nozzle exit, which can be determined much more readily than velocities at the film surface. When the comparison is made for nozzles comparably mounted, this becomes almost as convenient a parameter as the actual velocities at the film.

Other jet designs became of interest as soon as we had thus examined the performance of an air jet of known properties. It will be noted in Figs. 8, 9 and 10 and in some of those earlier, that this slit jet does not cool both edges of the frame equally. Instead the velocity and efficiency at the soundtrack side are less because of the differences in static pressure acting along a slit of constant width, and because of the forward momentum of the air stream. The air stream is seen to sweep at an angle upward and to the right across the aperture, and to vary erratically along its length. These differences, plus the difficulties of cooling the lower frame edge suggested that improved performance could be expected from design changes.

It is interesting to note — and it is a main theme of this article — that such opportunities for improved performance were shown clearly and graphically by the phosphor study. Without the help of this tool, the opportunities could be inferred from a study of the projection behavior of film in actual projectors, but only laboriously and as the result of an extended study.

Several jet designs were examined to test the phosphor method and see what flow patterns would result. Figure 11 shows the extreme nonuniformity obtained from a wider slit whose area becomes larger with respect to the cross section of the supplying duct. Although the slit extends the full width of the aperture, only half of the film width is cooled effectively.

Among the other interesting variations is the pattern of Fig. 12, obtained from a jet similar to the above except that the slit has been replaced by a row of 17 holes of 0.040-in. diameter each. The pattern shows the same general variation caused by the difference in static pressure; in addition, there are local variations caused perhaps by burrs and defects around the circumference of individual holes.

When these holes are reduced in size to a row of 28, each only 0.019 in. in diameter, as in Fig. 13, every individual stream of air is so small in diameter that the $\frac{9}{16}$-in. path length from jet to film and the interference from neighboring jets breaks up the air pattern and reduces the cooling efficiency.

Aerodynamic design was approximated next, in order to see whether expected benefits would be realized, with the construction of a single jet resembling a venturi or turbine nozzle, which makes more efficient use of the energy in the air stream. Construction of this jet is shown in Fig. 14, and the completely different phosphor pattern resulting, in Fig. 15. Despite the restricted air source and the inability to place the jet in the optimum position because of interference from light cone, it will be seen that this is a remarkably successful cooling pattern. There has been so much recent work on the design of flow surfaces for aircraft turbines etc. that still more satisfactory cooling jets probably could be chosen.

There is one difference between the fluorescent pattern shown in this test and that which would result if the comparison had been made with moving film in an actual projector with a conventional lamphouse — and this difference is emphasized by Fig. 15. The heat input to stationary film in the mock projector is more uniformly distributed across the aperture than that produced by the mirror or condenser image of a carbon-arc crater, and what conduction

Figs. 11–13. Phosphor patterns: cooling pattern of nozzle with wide slit (Fig. 11); cooling pattern of perforate nozzle containing 17 holes each 0.040-in. diameter (Fig. 12); cooling pattern of perforate nozzle containing 28 holes each 0.019-in. diameter (Fig. 13).

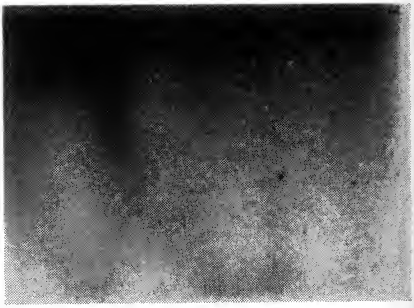


Figure 12

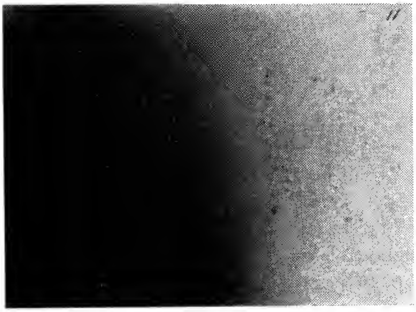


Figure 11

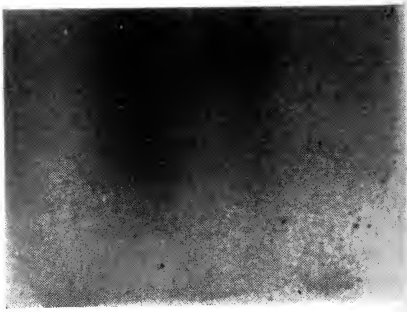


Figure 13

does occur in the steady-state model tends further to equalize the heating at the sides of the frame with that at the center. Thus, while Fig. 15 shows the film hotter at the frame edges and corners than at the center, because the cooling is less efficient at the edges than at the center, this temperature difference is reduced or reversed when film is projected with normal screen distribution — as is shown by the film testing of this jet. Actually this is the best cooling pattern obtained from any of the air jets studied because it is complementary to the heating pattern. It would of course be possible to adjust the intensity of the radiant energy heating various portions

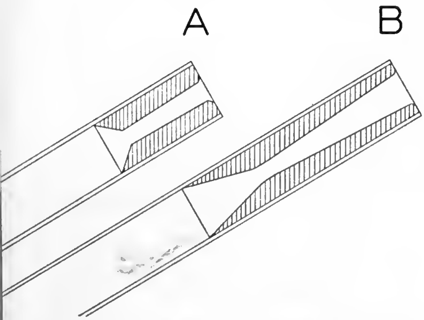
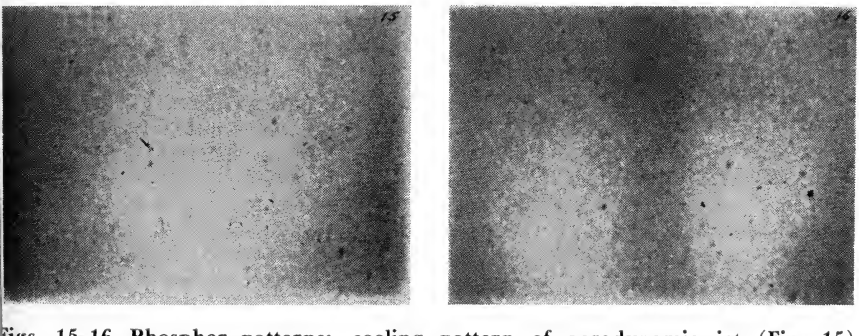


Fig. 14. Cross-section of aerodynamic jet, throat diameter 0.0952 in.: (A) as actually constructed; and (B) preferred contour.

of the stationary fluorescent film in the mock projector to obtain distributions typical of theater projectors, and this might make the fluorescent patterns easier to judge. All the examples published herein, however, used uniform energy distribution instead.

In passing it is interesting to examine the fluorescence pattern of Fig. 16, obtained by setting two jets each identical with that of Figure 14, directed at the horizontal centerline of the film, each about one-third of the way in from the sides of the frame. The two air streams interfere along a vertical line down the center of the frame, where the two airflow patterns come together to produce an area of low air velocity; cooling in this area is impeded. Since the "hot spot" is usually centered here, moreover, the jets perform even more unsatisfactorily because the hottest film areas get the least adequate cooling. It is found on actual projection of film that damage first occurs along the vertical centerline, confirming the fact that interference of the two air streams provides poor cooling there.

This fluorescent examination of air jets, therefore, produced one design — the venturi of Fig. 14 — that appeared considerably superior to the slit of Fig. 3. Having determined the apparent advantage of this design, this new jet was



Figs. 15–16. Phosphor patterns: cooling pattern of aerodynamic jet (Fig. 15), and cooling pattern of twin aerodynamic jets (Fig. 16).

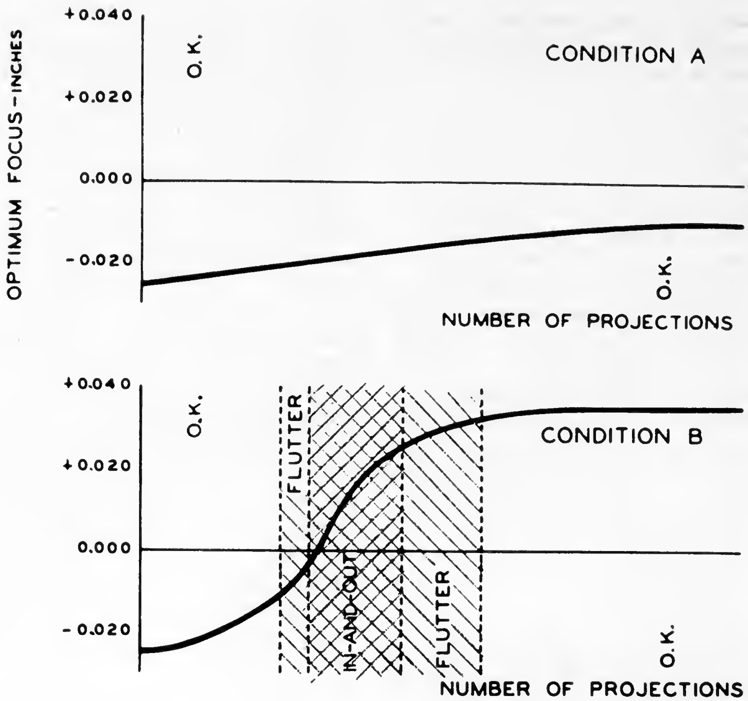


Fig. 17. Projection history of film as measured by changes in the point of best focus. If the point of best focus is determined for each projection of the film, the resulting curves can be related to film performance. This is particularly valuable for preliminary rapid testing to predict film behavior in the trade. A slow rate of change of focus, as in Condition A, is typical of good screen quality; a rapid rate of change of focus as in Condition B is always accompanied by poor image quality on the screen.

then compared with the older in a test with film itself, projected under normal conditions. This film comparison is the final evaluation of the screening done through the semiquantitative use of temperature-sensitive phosphors.

Confirmatory Film Testing

For the proper evaluation of projection apparatus by film testing, it is essential that the work be done with care, especially to insure that due account is taken of the severest possibilities and that the results can be interpreted practically without qualification.

Two procedures for the film evaluation of projection equipment have been described previously[1]: (1) the projection of experimental film, designed to provide permanent indication when its critical temperature has been exceeded, and (2) the projection of regular cine positive, under conditions where its focus changes with repeated projection and its variations in image quality can be determined.

For either of these tests to be meaningful, it is important that the film be freshly processed and that it not have been projected previously (such previous projection makes the film less critical and there is danger of an over-optimistic evaluation of the equipment). It is also necessary that the print include areas of adequate density, and that it be sharp

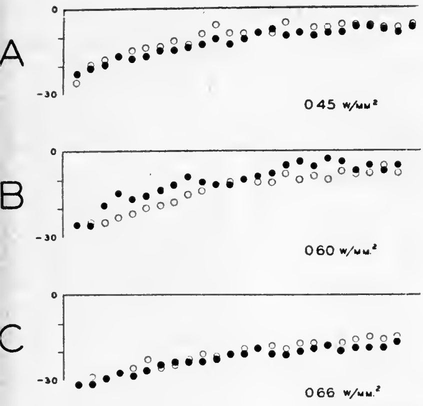


Fig. 18. Improvements in projection history of film with improvements in air cooling: (A) no air cooling; flux limited to 0.45 w/sq mm; (B) slit nozzle as in Fig. 5; flux limited to 0.60 w/sq mm; and (C) aerodynamic jet as in Fig. 15; flux limited to 0.66 w/sq mm.

and the action limited so that it will be possible to judge departures from ideal screen definition.

Comparison of nozzle designs by film testing was arranged to determine whether the venturi type (best of those tested by the phosphor technique) would maintain its advantage over the slit type (studied previously and found reasonably effective). In other words a comparison was made between the jet that gave the phosphor pattern of Fig. 15 and the jet that gave the phosphor pattern of Fig. 5.

When the experimental film procedure was applied to a study of these nozzles, the experimental film showed better performance with the jet of Fig. 14A. An increase in permissible flux densities of 5% to 10% over the limit for the slit nozzle was required before film cooled by the venturi jet reached its threshold temperature.

When the focus and image quality of normal cine positive — studied under critical conditions where changes in either factor can be measured carefully — were examined for evidence of differences between the two nozzles, a similar evaluation resulted. In this method of analyzing film behavior it has been shown that data like that of Fig. 17 are obtained, where Curve A represents good film behavior and satisfactory projection, Curve B poor film behavior and excessive projection conditions. This type of information obtained during loop projection tests of the two nozzles under test is shown in Fig. 18. It is apparent that the desirable curve shape A (cf. Fig. 17) can be otained with the slit jet for flux up to 0.60 w/sq mm, while with the venturi jet of Fig. 14-A, this same film behavior extends up to 0.66 w/sq mm — representing a 10% increase in effectiveness.

At the same time Fig. 18 shows that without air-cooling in this same equipment the limit is about 0.45 w/sq mm emphasizing the advantage gained from the cooling and positioning effects of air nozzles.

Recommendations

In this brief excursion into the proper design of jets for air-cooling, it has become apparent that the best design must take account of the equipment in which the jets are used. The most efficient design for one projector may be relatively inefficient for another in which the projector construction provides different air-flow paths, different opportunities for exhaust, etc. The outstanding advantage of the phosphor method of preliminary testing is that it makes the effects of such factors immediately visible. It is fortunately also relatively simple to apply, and therefore becomes a convenient tool for those designing projection equipment for maximum output.

Jet design to produce a symmetrical cooling pattern over the aperture area that complements the heating pattern has been shown to be a satisfactory design criterion, and the relative performance of various jets seems to be pictured adequately by the phosphor-temperature patterns. Because the present semiquantitative method does not show the level of cooling — except relatively — it is still necessary to examine the best design or the several best designs in actual film projection as final confirmation of their practical value.

From the work herein outlined it seems that the temperature-sensitive phosphors can be of real assistance in the design of projection equipment for increased screen illumination by illustrating graphically some of the design problems and shortening the engineering appraisal. It seems very likely that the method will prove equally advantageous for the engineering approach to other heat-transfer problems.

Conclusions

The temperature-sensitive phosphor method of determining temperature distribution has become a tool of great engineering use, especially when the circumstances permit a ready control of its variables. Applied to the design of air jets for cooling motion-picture film it makes visible much that would long be obscure, and it shortens the job of designing jets tailored to their environment. For those interested in obtaining maximum screen-light output for projection systems, this design method has much to offer.

Acknowledgments

The authors express their appreciation to C. J. Staud and C. R. Fordyce for continuing guidance from the very beginning of this problem, and to J. B. Hale for suggesting the method of solution. In addition many colleagues from the Eastman Kodak Co. have given great assistance — especially R. S. Battey and P. H. Preo who carried on the investigation of nozzle designs, D. R. Eastman who prepared the phosphor coatings, and N. R. Nail who assisted in devising suitable equipment.

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Stereo X-Ray Motion Pictures

By S. A. WEINBERG, J. S. WATSON, R. GRAMIAK and G. H. RAMSEY

In stereoradiography, image displacement is obtained either by shifting the x-ray tube, or, less often, by keeping the tube stationary and rotating the subject through a few degrees of angle between exposures. Either of the methods can be applied to stereo cinefluorography, but the rotational method has the advantage of not requiring special x-ray equipment. A single-film projector having two picture apertures for stereo projection of rotational films is described.

Stereo pairs of x-ray films are generally exposed in sequence, the first from a "right-eye" position of the x-ray tube and the second from a "left-eye" position. The correct amount of tube shift (anode or target separation) is not necessarily equal to average interpupillary distance, but varies in relation to such factors as tube-to-film distance and subject thickness,. the final criterion being the image displacement on the films. According to Klein, the stereo displacement of foreground image points should not exceed about 8.5 mm if the films are to be viewed at reading distance.[1]

This matter of anode separation has been one of the major problems in experimental work on three-dimensional x-ray motion pictures. Since it would obviously be impractical to shuttle an x-ray tube back and forth at motion-picture frequencies, the tentative solution of the problem has been to use not one but two x-ray tubes, energized alternately, or, as in Janker's early apparatus, continuously, with a revolving lead shutter to interrupt first one x-ray beam and then the other.[2] Meanwhile the motion picture camera copies the alternate right- and left-eye images as they appear successively on the fluorescent screen of the cinefluorographic unit.

Unfortunately the x-ray tubes suitable for motion-picture work are of such large diameter that their anodes cannot be brought much closer together than 15 cm. This is entirely too big a separation for average cinefluorography and can only be used with small, easily penetrable subjects at unusually long target-to-screen distances. It is true that in making full-scale stereo chest films the tube is sometimes shifted as much as 15 cm. But films of this sort are made with the tube 180 cm from the films and

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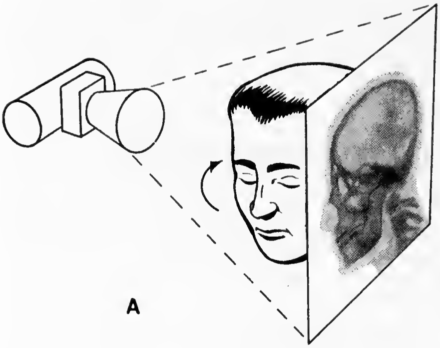
(This paper was received on March 18, 1954.)



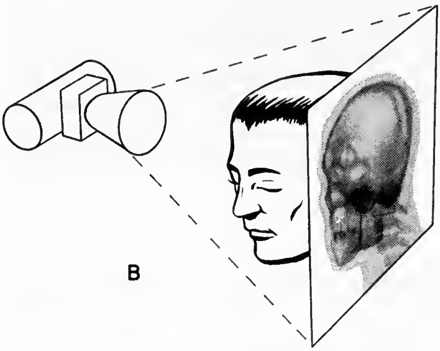


Fig. 1. Radiation from the x-ray tube (left) produces image of the subject on the film (or fluorescent screen). The first view is made with the subject in position A, the second in position B. The two views make up a stereo pair.

are viewed at 90 cm on a Wheatstone stereoscope. Furthermore, if there is eyestrain involved in fusing the images, the radiologist accepts it on the theory that eyestrain is indispensable to the localization of small details in depth. With stereo motion pictures, on the other hand, which are made at an average target-to-screen distance of 75 cm and viewed by projection, anode separations of more than a very few centimeters generally mean that the images cannot be fused at all.

What is probably needed here is a special x-ray tube with two separate anodes or focal spots capable of being energized alternately so as to produce first a right and then a left x-ray beam. Failing the special tube, something might be done with a pair of high-voltage sources at a distance from the screen of several meters. But if neither the special tube nor the high-voltage sources are forthcoming, the only course that remains is to abandon anode separation for a different principle.

Rotational Stereo

That rotational procedures are an aid toward seeing things in the round and in depth is a commonplace of routine x-ray work although such procedures are not necessarily stereoscopic methods. One of the most reliable ways of locating foreign bodies, for example, is to make two views at right angles, and this is done by rotating the subject 90° between exposures. Body section radiography, too, depends on rotational movements of the tube and film around the subject, while in fluoroscopy depth relations are most easily established by turning or rolling the subject from side to side.

What is not so generally known is the fact that subject rotation can be substituted for tube shift to make true stereo pairs of films. An ingenious apparatus for holding and turning (or inclining) the subject through a few degrees of angle between exposures has recently been described by Gordon and Sauro.[3] The location in depth of the axis around which rotation takes place apparently makes little difference to the ultimate stereo effect, since in x-ray work there is no perceptible horizon or background beyond the far edge of the subject's body.

It will be noticed that in the procedure just mentioned the exposures are made with the subject at rest, and that there is ample time for rotating the subject from position A (see Fig. 1) to position B. This starting and stopping of rotation is, of course, not practical at motion-picture frequencies. In motion-picture work the subject is therefore made to rotate continuously. The first motion-picture exposure "arrests" the subject in what corresponds to position A, the second exposure in position B, the third in position C, etc. The stereo "pairs" of frames, which will appear simultaneously on the projection screen, may consist of frames one and two, two and three, three and four, etc., or, if greater image displacement is desired, of frames one and three, two and four, three and five, etc.

So far as our own work in this field is concerned, it must be confessed that we came upon the rotational principle largely by accident and that we were not then aware of Janker's previous experiments, which included not only rotation of the subject in front of the tube, but rotation of the tube in an arc around the subject. We were attempting, at the time, to verify our theoretical anode separation figures by making stop-motion films of a skull at a target-to-screen distance of 75 cm. The stop-motion technique, of course, had the advantage of permitting the tube to be shifted back and forth by hand between exposures. The skull (an anatomical specimen) was mounted on an indexed turntable and was rotated 2 degrees for each stereo pair of negative frames. In all, 180 stereo pairs of frames were photographed, so that the skull made a complete revolution. The resulting right-eye frames were printed successively on one length of positive film, and the left-eye frames on another. The two prints were then made into continuous loops and run together on a stereo motion-picture projector.

As it turned out, the scenes which gave the best stereo illusion were those made with a tube shift of 2 cm. However, all of the skull scenes "stereoed" so much better than some other experimental scenes made with nonrotational types of stop motion that we began to wonder whether rotation alone without tube shift might not give a binocular stereo effect. We therefore projected two identical right-eye prints of the revolving skull, threading one of the prints in the projector in such a way that it led the other by one frame. Later we tried putting the prints out of step by two, three, and four frames and projecting them at different speeds. Some differences in ease of fusion were observed, but the fact remained that the stereo effect of the revolving views made with a single position of the tube was fully as good as that of the views made with tube shift.

The next step was to try out the rotational stereo method with living subjects at motion-picture speeds. The subject was placed in front of the fluorescent screen and rotated steadily through one complete revolution. Films were made in this way of the chest, the head and neck, the knee and ankle joints, and the hand and wrist. Scenes of this kind are quite effective when simply run through a standard, single-film projector. Within the chest, for instance, the constantly changing silhouette of the heart and slope of the diaphragm can be followed without too much difficulty, provided the observer has enough anatomical knowledge to orient him. But when the scene is run on the stereo projector, the boundaries and depth relationships of the structures are clear even to the least experienced.

Practical Difficulties

Both anode separation and rotational stereo cinefluorography suffer from the fact that their stereo "pairs" of frames cannot be exposed simultaneously, as in conventional stereo motion pictures, but must be exposed in sequence. With live subjects this means that there is often movement (other than stereo displacement) between one frame of the pair and the other. So long as the movement is horizontal the discrepancy is hardly noticed at all, but if a rapid vertical movement occurs, the local failure of the stereo illusion is quite disconcerting. Thus, when a swallow of a barium mixture progresses rapidly down the esophagus, its leading edge will be a focus of distraction all the way to the cardia (upper orifice of the stomach). Because of the usually greater time interval between its stereo pairs of frames, the rotational method is apt to be more seriously afflicted with this trouble than the anode separation method.

Another obvious source of dissatisfaction with rotational films is the constant turning round of the subject, which goes on relentlessly whether it is wanted or not. Important details are seen fleetingly and tantalize the spectator like girls on a merry-go-round. We need not carry the simile further except to note that, if rotation stops, the glamorous stereo illusion vanishes, and only reappears when rotation begins again.

Fig. 2. Typical setup for barium swallow study of esophagus. Patient on mechanized chair has turned 180° during 10-sec exposure. Rate of rotation can be varied for different camera speeds.

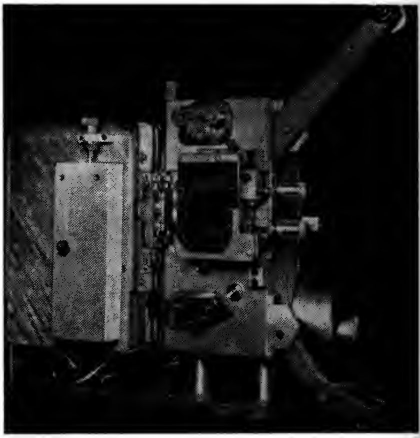


Fig. 3. Complete projector. First surface mirrors (behind Polaroid filter) are mounted 45° to film plane. Projection screen is at right angle to film plane.

Attempts to minimize the rotational element (while still retaining the stereo illusion) have been only moderately successful. It is not necessary, of course, to rotate the subject through the full 360°; in fact it is sometimes impossible. Angiocardiographic subjects,* for example, are encumbered with splints and tubing and can only be rotated through a limited angle. In cases of this sort the image displacement of the stereo pairs can be increased by moving the tube through an arc of 30° or 40° in a direction counter to the rotation of the subject, or, in still more extreme cases, the subject can be kept stationary and the tube alone moved. Unfortunately any departure from frank rotation tends to immobilize the structures which lie nearest the fluorescent screen in the background of the image. This in turn decreases the stereo displacement of the background elements and may weaken the stereoscopic illusion.

It should be noted that in the stereo pairs of frames made by the rotational

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* Radiographic visualization of the chambers and vessels of the heart by injecting a radio-opaque dye into the bloodstream.

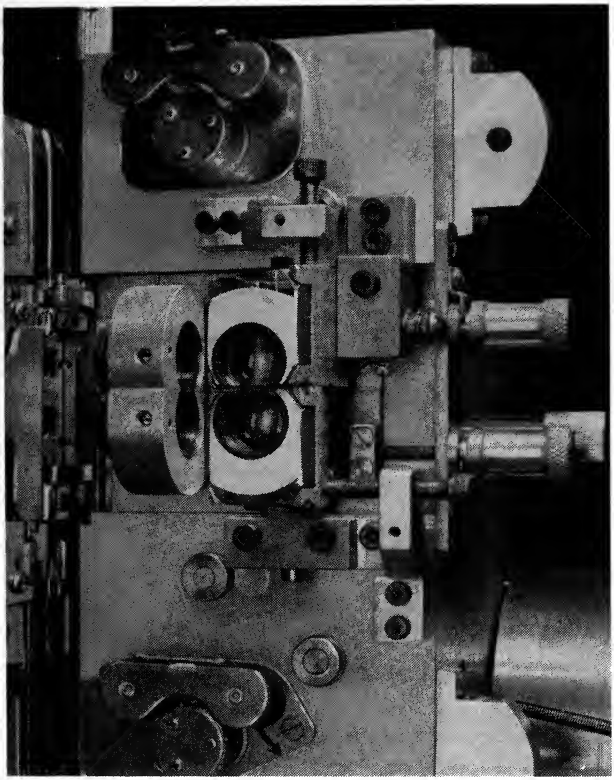

Fig. 4. Twin-aperture plate, matched lenses and first surface mirrors. Knurled extension on right are focus and threading adjustments. Top mirror rotates on horizontal axis, bottom mirror on vertical axis.

method the displacements of the foreground image elements, which lie in front of the center of rotation, take place not as in conventional stereo, against a background of increasingly static elements, but against a background of elements which are displaced in the opposite direction. Thus it can be said that the displacements which contribute to the stereo illusion are reinforced by the rotational method to the extent of being almost doubled. This "overdetermination" is helpful in the case of cinefluorographic scenes of thick subjects, which, for reasons mentioned in a previous paper, are often too unsharp for stereo treatment by the anode separation method.[4]

Apparatus

For exposing rotational films, no special x-ray equipment is needed, nor do there have to be any changes in the cinefluorographic unit. The motor-driven, revolving chair shown in Fig. 2 makes a good turntable for rotating the average subject, while, with subjects who can be rotated only a little or not at all, the tube is moved along a semicircular track through an arc of 20° with the x-ray beam centered on the fluorescent screen.

For projecting the films, the conven-

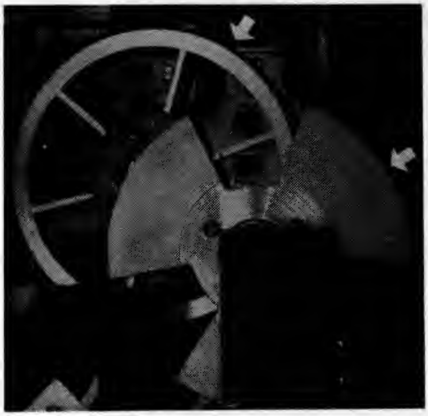

Fig. 5. Skeleton shutter which replaces original shutter. New shutter mounted below twin apertures.

tional twin stereo projector is satisfactory within its limitations, but it takes a long time to thread, is twice as liable to film breakage as a single-film projector, and has other faults which are only too well known to projectionists. Furthermore its two film channels are wasted on rotational films, since the prints from rotational negatives are not true right- and left-eye prints, and are only transformed into stereo pairs by "staggered" projection, which could be accomplished just as well in a single projector having two picture apertures.

While still working with the twin stereo projector we had found that the best stereo displacement for average subjects was obtained by simultaneous projection of frames one and three, two and four, three and five, etc. The special 16mm projector was accordingly designed with two picture apertures located vertically one above the other and separated by a distance between their center lines of 0.600 in. minus 0.003 in. to allow for film shrinkage. The film movement was borrowed from a Kodak Pageant projector, the standard film gate being replaced with a longer one to accommodate the two apertures (Fig. 3). Because of the close proximity of the picture axes, illumination was managed with a single lamp and condenser system. This expedient kept the size of the projector within usual 16mm limits, though at some expense of screen brightness. The lamp was made adjustable horizontally and the condenser vertically to take care of variations in lamp bases. To obtain stereoscopic effect, polarizing filters are placed over each of the two projector lenses and the projected image is viewed through polarizing spectacles.

The rest of the optical system consisted of two projection lenses, one for each aperture (Fig. 4). These had to be of relatively small diameter if their axes were to be brought within 0.597 in. of each other. A matched pair of Eastman Kodak "eyepiece components" was selected having focal lengths of 25 mm and apertures of *f*/1.9. The diameters of the lens barrels were further reduced locally by grinding flat areas along the adjacent sides to within a few thousandths of the edges of the glass elements, thus permitting the correct axis separation. The finished assembly has vernier focusing adjustments and the lenses can be moved separately or as a unit.

If we had had patience enough to modify the lenses further to bring their central axes to within 0.581 in. of each other this would have given us the proper vertical image alignment on the screen. However, to do this would have necessitated breaking through the lens barrel and grinding flats on the elements as well. A preliminary test showed that vertical alignment and horizontal adjustment could be managed by using first surface mirrors immediately in front of each lens and at 45° to the optical axes. One mirror is mounted on a vertical axis and the other on a horizontal axis. Considering that the images are projected parallel to each other, the vertical disparity on the screen is never more than the 1.5-cm lens separation. Consequently the slight rotation of the image (the roof prism effect of the mirror moving on the horizontal axis) is not enough to introduce any noticeable conflict.

In order to ensure uniform occultation of the two picture apertures, the original shutter (which also served as a drive pulley) was replaced with a skeleton shutter (Fig. 5), and a three-bladed shutter of 4-in. diameter was installed on a new shutter shaft located a little beneath the lower picture aperture. With this arrangement the periodic difference of illumination between the two pictures is so minute as to be negligible.

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2. Robert Janker, "Zur Frage der Röntgenstereoscopie," *Fortschr. an dem Gebiete der Röntgenstr. 71:* 339–344, 1949.
3. Elias Gordon and Joseph Sauro, "A new method of stereoscopic roentgenography," *Am. J. Roentgenol. 70:* 824, Nov. 1953.
4. S. A. Weinberg, J. S. Watson and G. H. Ramsey, "X-ray motion picture techniques employed in medical diagnosis and research," *Jour. SMPTE, 59:* 300–308, Oct. 1952.

Errata

J. D. Bick, "Methods of Measuring Surface Induction of Magnetic Tape," *Jour. SMPTE, 60:* 516–525, Apr. Pt. II, 1953.

The following confusion of terminology with respect to this paper has been brought to light.

Surface induction as defined by NARTB is "the flux density (B) at right angles to the surface of the tape." A recording having constant flux vs. frequency at the surface of the tape will have a surface induction which is proportional to frequency. The open circuit voltage output of an "ideal" short gap head is proportional to the rate of change of flux, or in other words proportional to frequency. Therefore, the open circuit voltage of the "ideal" short gap head is proportional to surface induction. What this means regarding the article is that all curves labelled "surface induction" and discussions of those curves show an error of 6 db/octave. The article would be correct if the words "surface flux" were inserted everywhere "surface induction" appears.

An error of a similar nature appears in one portion of the NARTB Recording and Reproducing Standards of June 1953 and the proposed standard of the CCIR (Doc. 789-E, 4 October 1953). This error is being acted upon by the respective bodies and will be corrected in the near future.

Committees of the Society as of March 16, 1954, Administrative Committees, *Jour. SMPTE, 62:* 327, Apr. Pt. I, 1954.

HONORARY MEMBERSHIP. *To search diligently for candidates who through their basic inventions or outstanding accomplishments have contributed to the advancement of the motion-picture industry and are thus worthy of becoming Honorary members of the Society.*

Fred T. Bowditch, *Chairman,* National Carbon Div., Box 6087, Cleveland 1, Ohio

F. A. Cahill   Lloyd Thompson   William C. Kunzmann   Elmer Richardson

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F. J. Kolb, Jr., *Chairman,* Eastman Kodak Co., 343 State St., Rochester 4, N. Y.

Carlos H. Elmer   Axel G. Jensen   J. E. Volkmann   W. Wallace Lozier

Pneumatic Pulldown 16mm Projector

By RAYMOND W. WENGEL

An experimental model of a 16mm projector is described in which air pressure is used to effect pulldown of the film. Some results of speed tests for this type of pulldown are discussed.

THE PNEUMATIC PULLDOWN is a device for advancing the film in the gate of a motion-picture apparatus by the direct application of air pressure to the film. At the Eastman Kodak Co. several pulldowns of various constructions, but all answering to this description, have recently been under experimental development.

One of them was carried to the point of a trial application in a pushbutton-operated repeater projector. This was installed in the George Eastman House of Photography at Rochester, N.Y., for test. The results attained in this work are of a preliminary character but are thought to be of sufficient interest to warrant presentation at this time in view of the current interest in rapid-acting pulldowns, and because there does not appear to have been a previous discussion of similar devices in the annals of the Society.

The mechanisms commonly employed for intermittently advancing the film in cameras and projectors are either reciprocating, as in the claw pulldown, or intermittently rotating as in the Geneva-driven sprocket. In both cases the effective masses of the moving parts often are much greater than the mass of the film to be moved so that to avoid vibration and noise the parts must be nicely fitted and substantially mounted.

Although these mechanical systems have been highly perfected and for the most part function satisfactorily under ordinary conditions, they become more difficult to design and make as the required speed of operation increases. A logical compulsion has thus arisen to attempt radical modifications of these devices or to find a new concept of the pulldown which would not carry with it the handicaps of large mass and precision manufacture.

The use of controlled air pressure acting directly on the loops of film adjacent to the gate to advance the film successfully removes the need for intermittently moving solid parts. In addition, by furnishing a convenient means for retaining the film under tension in the gate, air pressure permits the use of a fixed locating pin to engage the

Presented on October 7, 1953, at the Society's Convention at New York by Raymond W. Wengel, Camera Works, Eastman Kodak Co., Rochester 4, N.Y.
(This paper was received on March 24, 1954.)

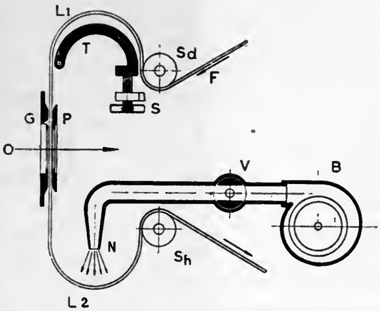


Fig. 1. Simplified air-pulldown principle.

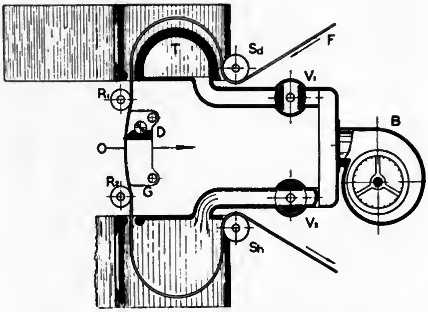


Fig. 2. Experimental air pulldown.

perforation so that a superior vertical steadiness results. Furthermore, if a curved gate is used, the pressure plate ordinarily required to hold the film stationary during the projection phase may be eliminated. In the latter case, there is practically complete relief from the evils that sometimes arise when film is moved between squeezing surfaces.

Before entering into a discussion of the Eastman House projector, it is perhaps desirable first to give some consideration to the principle of the air pulldown itself. Figure 1, the simplest case as well as one of historical interest, shows the bare elements of a pneumatic pulldown. This is substantially the same as the arrangement shown in a U.S. patent issued some 35 years ago to H. F. Evans of England. In this simplified representation S_d and S_h are the usual driving and holding sprockets respectively, L_1 and L_2 the upper and lower loops, G the gate and P the pressure pad. O is the optical axis. In place of a claw or Geneva sprocket, however, there is the nozzle N, rotary valve V and the blower B. The operation of the pulldown may be thought of as starting with the opening of valve V so that air passes through to the nozzle and thence is directed onto the lower loop. The tension thus created in the film of the lower loop overcomes the gate friction, and the film moves downward until the upper loop is pulled into contact with the limiting track T. Thereupon, the valve closes, shutting off the air to the lower loop and relieving the film tension. The gate friction then holds the film stationary while the new frame is projected. During this interval the upper sprocket feeds another frame length into the upper loop preparatory to the next pulldown stroke. Framing is accomplished by adjustment of the screw S which raises or lowers the track T. This changes the length of film included between the acting tooth of sprocket S_d and the gate at the moment the pulldown is completed. Unfortunately, a machine built strictly according to this diagram would not be satisfactory in operation and would fail to give the possible advantages of the pneumatic pulldown. For one thing, the vertical steadiness would be poor because the registering point is a tooth of the sprocket too remote from the gate. Also, the drag due to gate friction would seriously interfere with the attainment of a high speed of pulldown.

An independently conceived and different construction of the pneumatic pulldown is shown diagrammatically in Fig. 2. Here, in addition to the air supply to the lower loop, there is a similar supply to the upper loop under control of an upper valve V_1. The limiting track T remains as before, but is now of open construction so that air may pass through and push against the upper loop. To make efficient use of the air, side plates are provided to reduce leakage. The outer side plates are shown mounted on hinges and swung open as though for threading. The gate is represented by G and is curved concave towards the lens. It is fitted with rollers R_1 and R_2 to help keep the film in contact with the surface and with a fixed detent D having a sloping face upstream of the film and a radical face downstream. The detent thus engages the perforation in the manner of a ratchet pawl so that upward motion is prevented but downward motion is not impeded. So a downward pull on the film will cause it to be advanced in the gate, and an upward pull will cause it to be held in register against the detent. By positioning the detent suitably with respect to the gate aperture, it serves also as a locating pin to register the frame.

The operation of this pulldown system can now be followed easily. Supposing the bottom valve V_2 to be open, air flows into the lower loop, rapidly building up pressure therein and causing an expansion of the loop which draws the film downward in the gate. The motion is limited, as before, by the curved track T, but in this case the setting of the track and drive sprocket allows a slight overtravel to insure that the new perforation falls over the detent with some extra space between its lower edge and the bottom surface of the detent. Continued rotation of the valve V_2 causes it to shut off the air to the lower loop at this moment, but, at the same time, valve V_1 is opening and letting air flow into the upper loop. Now the upper loop tends to expand and give a retrograde motion to the film. Movement in this reverse direction, of course, is brought to an end when the lower edge of the perforation comes into contact with the detent D, thus locating the new frame in the gate. Air pressure is maintained in the upper loop during the projection period in order to keep the film tight against the detent. The air pressure in the lower loop is in the meantime rapidly falling by reason of the leakage through perforations and past the edges of the film. Even so, the residual pressure serves to maintain sufficient tension in the film below the detent to hold it in contact with the gate surface and keep the picture in focus. At the end of the stationary period the upper valve closes and the pressure in the upper loop is dissipated by leakage while the lower valve again opens allowing air to rush into the lower loop to initiate the next pulldown stroke. The successful operation of the system requires that the valves have the proper timing relative to the sprockets, and measure out the right proportion of air to each loop. The leakage rates at the loops also must be set at suitable values. None of these factors, however, is of a critical nature, and it is, therefore, possible with ordinary quality of manufacture to have a smoothly running machine. The use of the fixed detent at the aperture insures a high degree of vertical steadiness.

The two loops of this pulldown might bear comparison to the pistons of a gas engine. In operation, the sound produced is even more strikingly suggestive of a gas engine. Fortunately, this sound, which originates in the sudden discharge of air into the loops, is but feebly coupled to the solid structures of the machine and can be almost entirely done away with by a simple acoustical case.

The opportunity to apply the pneumatic pulldown came about through the need for reliable repeating projectors in the George Eastman House of Photography in Rochester. The chief requirements in the application were to extend the period between necessary servicing stops and to increase greatly the useful life of the film.

The pneumatic principle, it was thought, would contribute to the life of the film in projection because the absence of a pressure pad greatly reduces friction in the gate, and, therefore, the force acting on the perforation edge

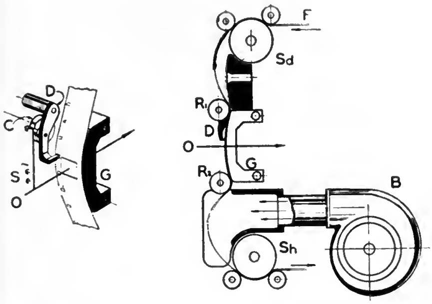


Fig. 3. Air-pulldown mechanism of repeater projector.

during pulldown is significantly less. For the same reason, there is much less chance of the film sticking in the gate and consequent failure of the pulldown.

The pneumatic pulldown selected for this application differs from that just described and is shown diagrammatically in Fig. 3. It was felt that the fixed detent in the gate of the previous example would, after many round trips of the film, have a tendency to tear the top edges of the perforations as they slid down the sloping surface. To avoid this, the fixed detent was replaced in the new form by the cam-operated movable detent shown at D. Advantage was taken of this change also to get rid of the bulky rotary air valves. It was no longer necessary to have air pressure in the upper loop to keep the perforation edge against the detent. Instead, a constant pressure in the lower loop could be used, both to hold the edge against the detent and effect the pull-down when the detent is withdrawn from the perforation. As before, the gate is curved and a limiting track is used to control the amount of film displaced. The loops themselves are more flattened than those shown before. This secures an advantageous bow string action.

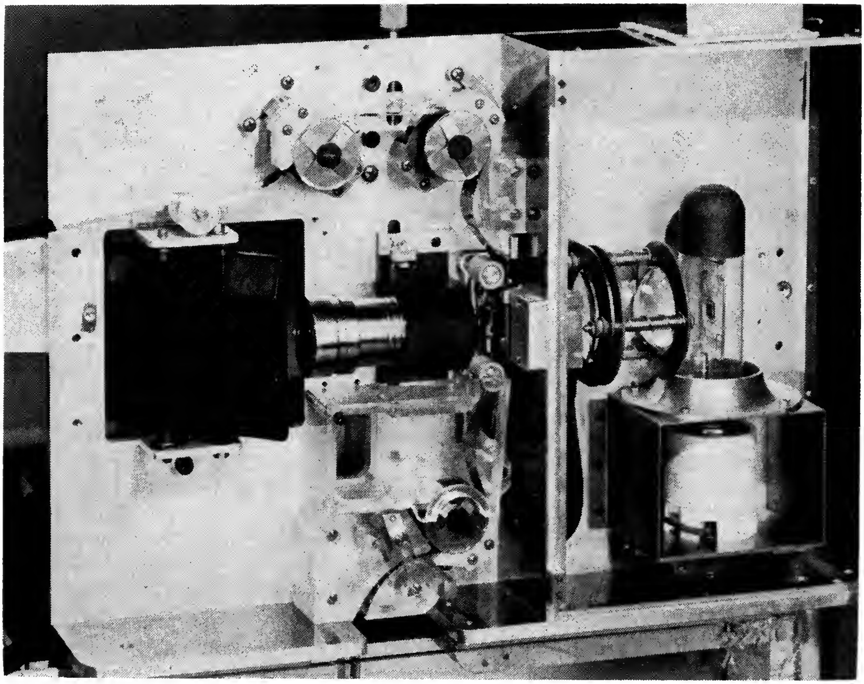


Fig. 4. Repeater projector mechanism.

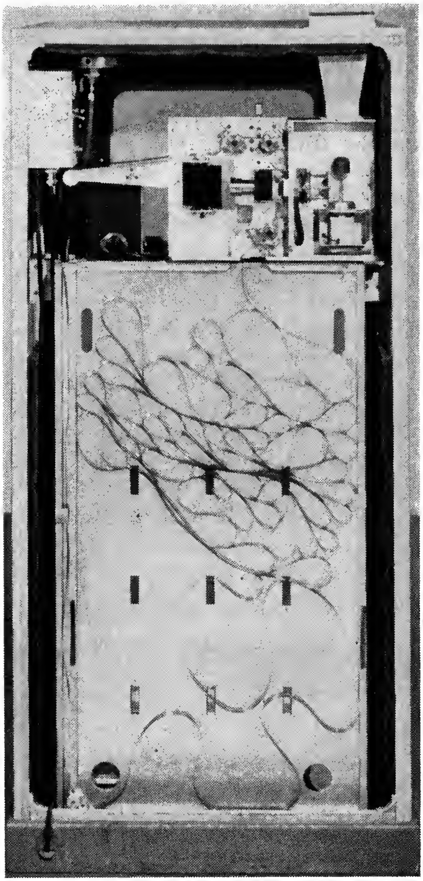


Fig. 5. Endless-loop film magazine.

For example, just before the detent is withdrawn, the lower sprocket has fed all except about a half frame out of the lower loop so that this loop is nearly flat. As a result, the film tension is considerably increased, a greater force is developed to overcome gate friction, and a greater initial acceleration occurs than would result with the semicircular loops. Similarly, the upper loop flattens as the pulldown stroke nears the end and this, together with the reaction of trapped air between the loop and fixed track, helps to decelerate the film. Control of the cushioning effect is afforded by proper sizing of the hole leading through the fixed track from under the loop to the outside.

The movable detent D is of such small size and mass that only a relatively small pressure of the spring S is needed to make it follow the cam C. For this reason, the point of the detent does not damage the film if at any time it should fail to enter the perforation and instead rub against the moving film. Test runs have shown consistently that film life with or without the detent in operation is the same.

Figure 4 is from a photograph of this projector showing the pulldown mechanism. Figure 5 shows the projector mounted in the cabinet. Space does not permit a description of all the auxiliary devices associated with this machine but it may be of interest to consider the continuous loop film magazine seen just beneath the projector in Fig. 5.

The magazine is a tall, thin, rectangular box holding film looped back and forth in a random manner. The back of the box is a flat aluminum plate and the front is of plate glass to allow observation of the film. The space between the plates is somewhat greater than the width of the film and at the edges is closed in by narrow strips of wood undercut in their inner faces to avoid contact with the picture area. A gap in the top permits entry of the film as it comes from the projector. At the lefthand bottom corner is a similar gap fitted with a roller underneath which the film passes to the vertical channel and then back to the projector.

The feature of interest is that the loops of film are supported by a current of air flowing upward in the magazine. Were it not for this current, the loops would fall to the bottom where the lowest would tend to be crushed flat and permanently creased. The film would then, of course, be unfit for projection.

The supporting air enters the magazine through holes at the bottom of the back plate and flows upward through the mass of loops to exhaust ports near the top. These are the two uppermost elongated slots in the back plate. A counter current of air flows downward from the top toward the exhaust ports and is of value in that it assists in spreading out the loops as they are formed. Control of the air flow to suit the quantity of film in the magazine is effected by a manual valve in the air line to the bottom holes and by an adjustable bypass in the vacuum line to the exhaust ports. It happens that in the illustration the air flow is excessive and has caused the loops to ride too high in the magazine. The difference in pressure required from bottom to top ranges from 0.1 in., water gauge, for shorter lengths, as for instance 100 ft, to 1-in. pressure for a full capacity of 400 ft. As an additional precaution against loading of the outgoing film by loops that might otherwise press upon it, there are three curved spring fingers reaching through the rectangular slots, seen just above the bottom air holes. These lightly interfere with the film loops at this level. In effect, the fingers form a false bottom to the magazine beneath which the film is free to be drawn out by the projector. Similarly, when the machine is stopped and air flow is no longer present to support the film, retractable soft rubber pads, seen in the remaining six rectangular slots, are pressed forward to securely clamp the film loops against falling to the bottom.

This experimental combination of pneumatic pulldown projector and pneumatic film magazine has proven to be more satisfactory than the commercially available equipment in use at the Eastman House. The first trial, over a period of several months, resulted in 1834 runs of a single 200-ft length before cracking at the corners of the perforations brought an end to the test. Other test runs made over a shorter period of time and with the projector running continuously gave an average of more than double this figure. It is believed that a useful life of 5000 runs will be attained when certain improvements are made in the projector.

It was indicated earlier that the pneumatic pulldown should be capable of high-speed operation. Referring again for the moment to the two-valve type shown in Fig. 2, it is clear that the air pressure in the lower loop is the main factor determining the speed. For example, a 90° pulldown for 16mm film requires only a moderate pressure of 3–4 in. water gauge. The maximum usable pressure was found to be 14 in. or about one-half pound per square inch. Above this pressure the edges of the perforations engaging the sprocket teeth would buckle. The speed attained with this pressure corresponded to a pulldown angle of 15° at 24 frames/sec, or a time of 1.7 msec. As a matter of curiosity, pictures were projected with this speed of pulldown but without a shutter. It was interesting to note that only scenes containing horizontal boundaries of high contrast were marred by a faint but objectionable ghost image due to the frame in its lowest position before it was pulled upward into register against the detent.

To raise the working pressure further it was found necessary to clamp the film at the sprockets in some manner that would distribute the force throughout the cross section instead of concentrating it at the perforation edge. To simplify the apparatus for initial trial a film strip was merely clamped at the ends, allowing about $1\frac{1}{2}$ frames slack to form the upper and lower loops. A moderate, constant air pressure was applied to the upper loop to draw the film back to its initial position after each pulldown stroke. In this way, the same piece of film could be repeatedly pulled down at speeds dependent upon the pressure applied to the lower loop.

At 4 psi the film withstood more than 300,000 successive pulldowns without breaking, and the stroke time measured 0.8 msec. The ultimate for this setup was reached with 7 psi. At this pressure the film strips would on an average last for 1,000 successive pulldowns. The duration of the pulldown stroke was 0.5 msec.

The experimental work done with the air pulldown indicates that it may find a place in the design of future motion-picture apparatus. A greater force may be applied to the film with relative ease by air pressure to effect a shorter time of pulldown or to increase the length of pulldown stroke. Air pressure maintained in the upper or lower loop can conveniently be used to keep the film under tension in the gate and held against a registering pin so that the pressure plate friction can be reduced or eliminated altogether, and a high degree of vertical steadiness results. The experimental operation of the cabinet projector described above gives evidence that the air pulldown would be desirable in automatic or pushbutton-operated projector systems because it is easier on the film, and loss of loop, if it occurs, is only momentary and rarely results in damage to the film. Although other possible applications have not as yet been worked out in detail, there would seem to be many places in which the air pulldown might be a satisfactory element of design.

American Standards

PH22.2, -.3, -.17, -.36, -.94 — 1954

Five American Standards approved by the American Standards Association on April 5 1954, are published on the following pages. The first four are revisions of previous standards, while the last one is new. These five standards were published previously for trial and comment and the background information on their development and processing will be found in the May 1953 *Journal* for PH22.2 and -.3 in the June 1953 *Journal* for -.17 and -.36, and September 1953 *Journal* for -.94 — *Henry Kogel*

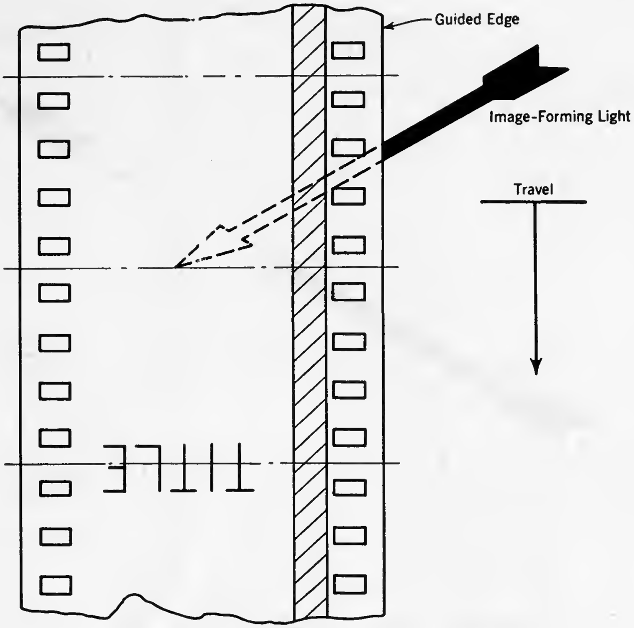
American Standard

35mm Sound Motion-Picture Film Usage in Camera

ASA
Reg. U.S. Pat. Office

PH22.2-1954
Revision of Z22.2-1946

*UDC 778.5



Drawing shows film as seen from inside the camera looking toward the camera lens.

1. Position of the Emulsion

1.1 Except for special processes, the emulsion shall be toward the camera lens.

2. Rate of Exposure

2.1 The rate of exposure shall be 24 frames per second.

3. Relationship Between Sound and Picture

3.1 The apparatus and film shall be so arranged that the sound is placed on the film 20 frames, ± ½ frame, ahead of the horizontal centerline through the corresponding picture. Thus, a given point on the film shall pass the soundhead after it has passed the picture aperture.

Approved April 5, 1954, by the American Standards Association, Incorporated
Sponsor: Society of Motion Picture and Television Engineers

*Universal Decimal Classification

Printed in U.S.A
ASA½M554

Price, 25 Cents

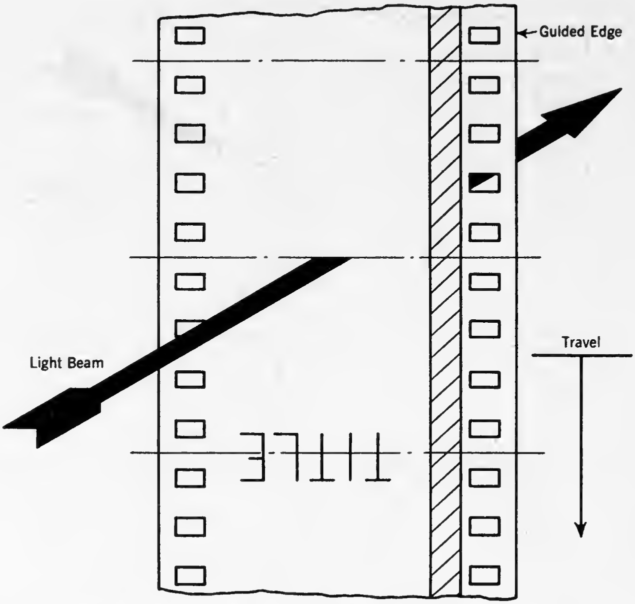
American Standard

35mm Sound Motion-Picture Film Usage in Projector

ASA
Reg. U.S. Pat. Office

PH22.3-1954
Revision of Z22.3-1946

*UDC 778.5



Drawing shows film as seen from the light source in the projector.

1. Position of the Emulsion

1.1 Except for special processes, the emulsion shall be toward the light source of the projector.

2. Rate of Projection

2.1 The rate of projection shall be 24 frames per second.

3. Relationship Between Sound and Picture

3.1 The apparatus and the film shall be so arranged that when the film is threaded normally, the soundtrack is scanned for reproduction at a point 20 frames, ± ½ frame, ahead of the centerline through the picture being projected. Thus, a given point on the film shall pass the soundhead after it has passed the picture aperture.

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*Universal Decimal Classification

Printed in U.S.A
ASA½M554

Price, 25 Cents

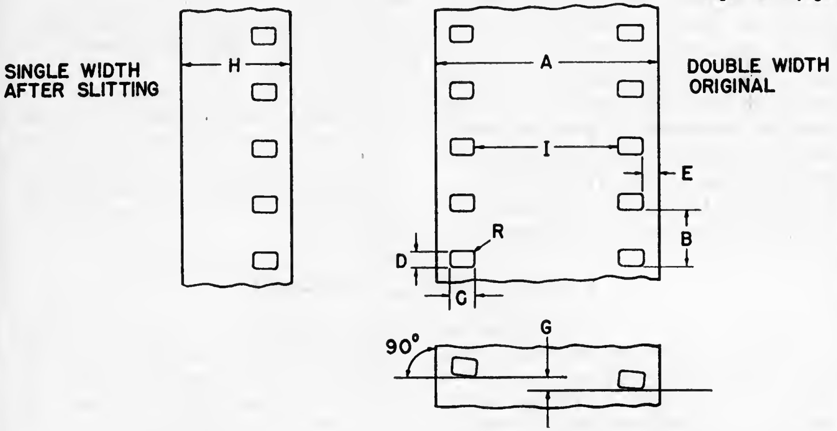
American Standard

Dimensions for 8mm Motion-Picture Film

ASA
Reg. U.S. Pat. Office

PH22.17-1954
Revision of Z22.17-1947

*UDC 778.5:771.5



Dimensions	Inches	Millimeters
*A	0.629 ± 0.001	15.98 ± 0.03
†B	0.150 ± 0.0005	3.810 ± 0.013
C	0.072 ± 0.0004	1.83 ± 0.01
D	0.050 ± 0.0004	1.27 ± 0.01
*E	0.036 ± 0.002	0.91 ± 0.05
G	Not > 0.001	Not > 0.025
H	0.314 ± 0.002	7.98 ± 0.04
I	0.413 ± 0.001	10.490 ± 0.025
‡L	15.000 ± 0.015	381.00 ± 0.38
R	0.010	0.25

These dimensions apply to negative and positive raw stock immediately after cutting and perforating.

* For low-shrink film as defined in Appendix 2, A shall be 0.628 ± 0.001 and E shall be 0.0355 ± 0.0020.

† In any group of four consecutive perforations, the maximum difference of pitch shall not exceed 0.001 inch and should be as much smaller as possible.

‡ This dimension represents the length of any 100 consecutive perforation intervals.

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*Universal Decimal Classification

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ASA½M554

Price, 25 Cents

(These Appendixes are not a part of the foregoing Standard.)

Appendix 1. Uniformity of Perforations

The dimensions given in this standard represent the practice of film manufacturers in that the dimensions are for film immediately after perforation. The punches and dies themselves are made to tolerances considerably smaller than those given, but owing to the fact that film is a plastic material, the dimensions of the slit and perforated film never agree exactly with the dimensions of the punches and dies. Shrinkage of the film, due to change in moisture content or loss of residual solvents, invariably results in a change in these dimensions during the life of the film. This change is generally uniform throughout the roll.

The uniformity of perforation is one of the most important of the variables affecting steadiness of projection.

Variations in pitch from roll to roll are of little significance compared to variations from one sprocket hole to the next. Actually, it is the maximum variation from one sprocket hole to the next within any small group that is important. This is one of the reasons for the method of specifying uniformity in dimension B.

Appendix 2. Shrinkage Characteristics

In the early days of 16mm film the safety base used for this film had the characteristic of shrinking very rapidly to a certain fairly definite amount and then not shrinking much more. Although this film tended to swell at high humidities, nevertheless the shrinkage that occurred in the package before the user received the film was always at least as great as any swell that might occur due to high humidities at the time of use. This meant that the user never encountered film, even at high humidities, that had greater width than that specified in the standards. This meant that camera and projector manufacturers seldom ran into trouble so long as their film gates would readily pass film at the upper limit of the slitting tolerances, namely 0.630 inch.

Within the past few years, however, a safety base with lower shrinkage characteristics began to be used. Although this film was less susceptible than the previous film to swelling at high humidities, nevertheless the shrinkage characteristics were low enough so that this shrinkage did not always compensate for the swell at high humidities. For this reason film slit at the mid point of the tolerance for width, namely 0.629 inch, would occasionally swell at high humidities to such an extent that it would bind in film gates designed to pass film with the width of 0.630 inch. The manufacturers, therefore, were compelled to slit at the lower edge of the tolerance permitted by the American Standard. Variations in their slitting width, however, sometimes produced film slit below the limits of the standard.

For this reason an alternate standard has been adopted for this low-shrink film in order that the manufacturers may slit within the standard and still produce film which does not exceed 0.630 inch even at high humidities.

For the purpose of this specification, low-shrink film base is film base which, when coated with emulsion and any other normal coating treatment, perforated, kept in the manufacturer's sealed container for 6 months, exposed, processed, and stored exposed to air not to exceed 30 days at 65 F to 75 F and 50 to 60% relative humidity and measured under like conditions of temperature and humidity, shall have shrunk not more than 0.2% from its original dimension at the time of perforating.

This definition of low-shrink film is to be used as a guide to film manufacturers, and departure therefrom shall not be cause for rejection of the film.

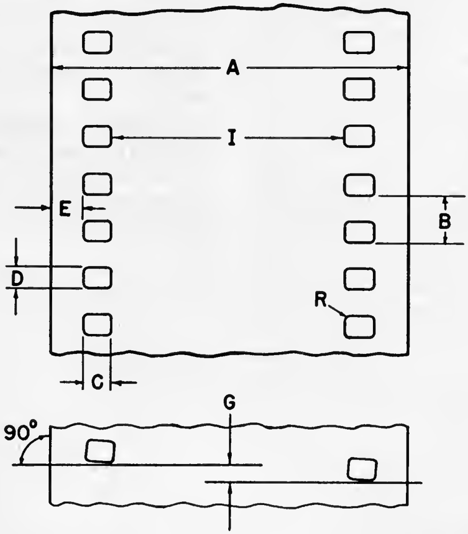
PH22.17-1954

American Standard
Dimensions for 35mm Motion-Picture Positive Raw Stock

ASA
Reg. U.S. Pat. Office

PH22.36-1954
Revision of Z22.36-1947

*UDC 778.5:771.5



Dimensions	Inches			Millimeters		
A	1.377	±	0.001	34.98	±	0.03
B	0.1870	±	0.0005	4.750	±	0.013
C	0.1100	±	0.0004	2.794	±	0.01
D	0.0780	±	0.0004	1.98	±	0.01
E	0.079	±	0.002	2.01	±	0.05
*G	Not	>	0.001	Not	>	0.025
I	0.999	±	0.002	25.37	±	0.05
†L	18.70	±	0.015	474.98	±	0.38
R	0.020			0.51		

These dimensions apply to the film immediately after cutting and perforating. This film is used for motion-picture prints and sound recording.

* Method of indicating G is the main change from Z22.36–1947.

† This dimension represents the length of any 100 consecutive perforation intervals.

Approved April 5, 1954, by the American Standards Association, Incorporated
Sponsor: Society of Motion Picture and Television Engineers

*Universal Decimal Classification

Printed in U.S.A.
ASA½M554

Price, 25 Cents

Appendix

(This Appendix is not a part of the foregoing Standard.)

The dimensions given in this standard represent the practice of film manufacturers in that the dimensions are for film immediately after perforation. The punches and dies themselves are made to tolerances considerably smaller than those given, but owing to the fact that film is a plastic material, the dimensions of the slit and perforated film never agree exactly with the dimensions of the punches and dies. Shrinkage of the film, due to change in moisture content or loss of residual solvents, invariably results in a change in these dimensions during the life of the film. This change is generally uniform throughout the film.

The uniformity of perforation is one of the most important of the variables affecting steadiness of projection.

Variations in pitch from roll to roll are of little significance compared to variations from one sprocket hole to the next. Actually, it is the maximum variation from one sprocket hole to the next within any small group that is important.

PH22.36-1954

American Standard

Slides and Opaques for Television Film Camera Chains

ASA
Reg. U.S. Pat. Office

PH22.94-1954
Supplement to Z38.7.19-1950

*UDC 778.5

1. Scope

1.1 This standard is intended to supplement American Standard Dimensions for Lantern Slides, Z38.7.19–1950, not replace it. The television system imposes special requirements that did not enter into the preparation of Z38.7.19–1950.

1.2 The standard applies only to slides and opaques intended for transmission in the standard fashion via a film camera chain. For other applications, such as background projection, the usual television requirements may not apply.

2. Standard Dimensions

2.1 Nominal Size. Only the four nominal sizes listed in column 1 of the table shall be considered standard for use in television film camera chains.

2.2 Overall Dimensions. The overall dimensions for any nominal size shall comply with the dimensions tabulated in column 2. (See Note 1.)

2.3 Dimensions of Transmitted Picture. The portion of the slide or opaque intended for transmission shall lie within a centrally located rectangle having the dimensions shown in column 3. (See Note 2.)

2.4 Dimensions of Picture Background. The background (or the pictorial material) of the slide or opaque shall extend without interruption over a centrally located rectangle having the dimensions shown in column 4. (See Note 3.)

2.5 Centering Tolerance. The center of the transmitted picture rectangle and the center of the background rectangle shall both lie within a circle having as its center the center of the slide and as its radius the dimension tabulated in column 5.

Note 1. The overall dimensions are in accord with American Standard Dimensions for Lantern Slides, Z38.7.19–1950, insofar as it is relevant. The thickness of opaques is not covered by Z38.7.19–1950. This quantity is here specified as 1/32 inch on the assumption that opaques will consist of double-weight photographic paper without additional support or backing.

Note 2. The dimensions shown for the transmitted picture are those which will be scanned by a perfectly adjusted film camera chain. To allow for some misadjustment of the film camera chain and an additional misadjustment in the home receiver, it is recommended that all essential information be contained in a centrally located area appreciably smaller than that specified in column 3.

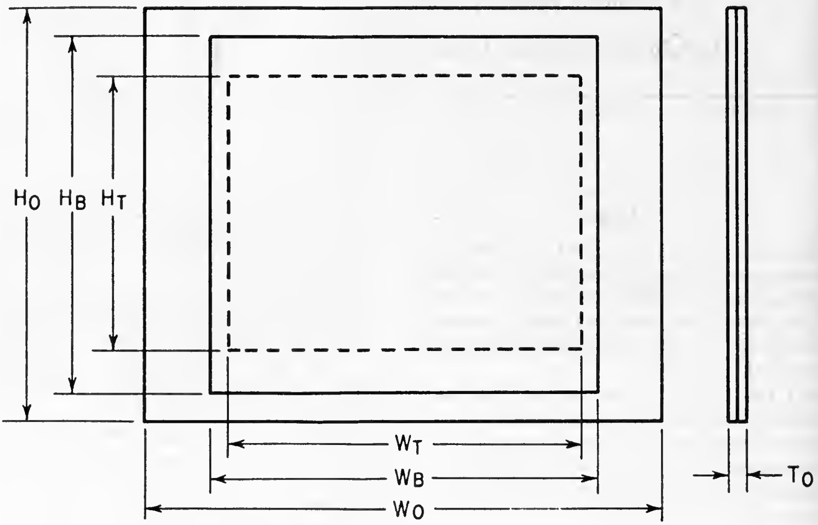
Note 3. In the case of slides, the background rectangle should be defined by an opaque mask to limit the stray light entering the film camera chain. The dimensions specified in column 4 permit the use of masks which comply with Z38.7.19–1950. For opaques, masking is generally provided by the projection equipment.

Approved April 5, 1954, by the American Standards Association, Incorporated
Sponsor: Society of Motion Picture and Television Engineers

*Universal Decimal Classification

Printed in U.S.A.
ASA½M554

Price, 25 Cents



(1) Nominal	(2) Overall			(3) Transmitted Picture		(4) Picture Background		(5) Centering Tolerance
	H_O	W_O	T_O max.	H_T max.	W_T max.	H_B min.	W_B min.	
2 × 2 slide (double 35)	$2^{+0}_{-1/32}$	$2^{+0}_{-1/32}$	⅛	27/32	1⅛	29/32	1 11/32	1/64
3¼ × 4 slide	$3\frac{1}{4}{}^{+1/64}_{-1/32}$	$4^{+1/64}_{-1/32}$	5/32	2 1/16	2¾	2¾	3	3/64
3¼ × 4 opaque	$3\frac{1}{4}{}^{+1/64}_{-1/32}$	$4^{+1/64}_{-1/32}$	1/32	2 1/16	2¾	2¾	3	3/64
4 × 5 opaque	4 ± 1/32	5 ± 1/32	1/32	3	4	3 3/16	4¼	1/16

All dimensions are in inches

PH22.94-1954

American Standard—Z57.1–1954

The American Standard, Method for Determining Flutter Content of Sound Recorders and Reproducers, Z57.1-1954, was approved by the American Standards Association on March 16, 1954, marking the conclusion of some eight years of effort.

This Standard was first proposed and the basic approach developed in 1946 by the Sound Committee of the Society under the chairmanship of John G. Frayne and was published for comment as a proposed standard in the August 1947 *Journal.* As a result of this publication, rather extensive comments were received from all fields of sound recording.

In October 1947 the American Standards Association set up a Sectional Committee on Sound Recording, Z57, sponsored jointly by the Institute of Radio Engineers and the Society. This proposed standard was referred for processing as its first American Standards project. In view of the comments that had been received, a subcommittee of Z57 under the chairmanship of Dr. E. W. Kellogg was appointed to attempt to resolve differences pointed up by these suggested modifications and to prepare another draft. This first Z57 draft, Z57/19, was circulated to the Z57 subcommittee and to the Sound Committee of the Society. The Sound Committee informed Dr. Kellogg's group that they desired further changes and in October 1948, a second draft, Z57/42, was circulated to all concerned.

Following circulation of this additional draft many months elapsed during which a consensus could not be reached on the matter of including weighted flutter and the flutter index. Also, some difference of opinion existed as to how to define such terms as flutter, flutter rate, flutter index, etc.

In January 1950 the third draft, Z57/58, which was thought to be acceptable, was duplicated and sent to the chairmen of the appropriate committees of the IRE, SMPTE, RMA and ASA. This limited circulation resulted in a few minor changes which were incorporated in still a fourth draft, Z57/63, which was sent to letter ballot of the Z57 Sectional Committee on August 10, 1950. It was still not possible to reach agreement, however, so this ballot was withdrawn. Further work on the proposed standard was undertaken by the Z57 subcommittee in an attempt to iron out the remaining differences regarding the definitions for flutter, flutter index, and weighted flutter. Agreement was finally reached on flutter and flutter index, and it was decided to omit all reference to weighted flutter in order to clear away the last obstacle.

This fifth draft, Z57.1/68, was approved by Sectional Committee Z57 on February 15, 1952, was subsequently approved by both sponsors of Z57, and has now become an American Standard.

It should be noted that the 1948–1952 SMPTE Sound Committee, under the chairmanship of Lloyd Goldsmith, played an important role in the development of this Standard; credit should also be given to William H. Deacy, Staff Engineer of the SMPTE for part of this period, for his considerable labor in shepherding this project through its manifold procedures and channels.

On July 15, 1953, the SMPTE withdrew its sponsorship of Sectional Committee Z57 leaving the IRE as sole sponsor. In its role as sponsor of Z57, the IRE has published this American Standard in the March 1954 issue of its *Proceedings*, page 537. Copies of the Standard can be purchased at 75¢ per copy directly from the IRE, 1 East 79 St., New York, N. Y.—*Henry Kogel*, Staff Engineer.

Section Meetings

The **Central Section** met on February 25, 1954, at the Western Society of Engineers. Malcolm G. Townsley, Assistant Vice-President and Director of Research, Bell & Howell Co., Chicago, presented a paper entitled "Photometry in Motion Pictures." As a well-qualified expert in this field, Mr. Townsley discussed the fundamental concepts of photometry and their application to motion picture production. He also included a discussion of the photometric properties of the special type of screens now being used for motion-picture projection.

A second paper was given by Carl F. Jensen, Regional Engineer for the Mid-American Region, Westinghouse Electric Corp., Lamp Div., Chicago, on "Some Projection Lamp Characteristics." From his broad experience in this particular field, Mr. Jensen presented an explanation in simple terms on the design of projection lamps and the optics involved. He also discussed reasons for short life of lamps and the factors that cause lamp problems in projection.

The March meeting of the Section was held on March 4 at Kimball Hall in Chicago. This was a joint meeting with the I.R.E. and the A.I.E.E., and the pre-meeting dinner was attended by 125 persons. A paper on "Color Television Receivers" was presented by William O. Swinyard, Chief Engineer of Hazeltine Research, Inc., who discussed in basic terms recent color television developments. He then described the NTSC television signals, the general nature of monochrome and color television set design, color resolution problems, and the solving of interference and transmission difficulties. The talk was well illustrated with excellent slides. Interest in the subject was so great that people had to be turned away at the door for lack of seating. It is estimated that some 400 people were present, including 100 members of the Section.—*K. M. Mason*, Secretary-Treasurer, Central Section, 137 N. Wabash Ave., Chicago.

The March meeting of the **Pacific Coast Section** was held at Paramount in Hollywood on the evening of March 23. Attendance was limited to members only, on a pre-reservation basis. Two sessions were held and both were filled to capacity, with a total attendance of 340 members. The subject was VistaVision, Paramount's new technique in motion-picture photography and projection.

C. R. Daily, Chief Optical Engineer at Paramount, described the process by which greater overall resolution is obtained in large-screen presentation. A wide-angle camera lens exposes an area 2½ times the normal size and at right angles to its normal position on the standard 35mm negative. The image is returned to its normal position for standard projection on the release film. A picture is composed for a normal 1.85:1 aspect ratio. Demonstrations from current color productions were shown at various aspect ratios on a new seamless curved screen 63 ft wide and 34 ft high.

Louis Mesenkop, Assistant Sound Director at Paramount, explained that a single photographic soundtrack will be provided with VistaVision. Three subaudio control signals will be superimposed on the track to permit presentation of dimensional sound in theaters equipped with suitable multiple channel and control facilities. This meeting was arranged through the courtesy of Loren Ryder, Director of Engineering and Recording for Paramount.—*E. W. Templin*, Secretary-Treasurer, Pacific Coast Section, c/o Westrex Corp., 6601 Romaine St., Hollywood 38.

The third meeting of the Board of Managers of the **Atlantic Coast Section** was held on March 24 at the Eastman Kodak Co. offices, 342 Madison Ave., New York City. On behalf of Everett Miller, the Chairman, George H. Gordon reviewed Mr. Miller's meeting with the Society's Board of Governors during the latter part of January. In particular, this involved consideration of the Atlantic Coast budget. It was announced that due to the reduced money available the program announcements used during the year 1953 had been changed to a postcard format. The members agreed to this change and further discussions were held concerning possible means of reducing current expenses.

It was agreed that the Section aim at an overall program of eight meetings for the calendar year 1954. This would provide r regular monthly meetings except during ıe months of June, July, August and ecember. It was also announced that efinite arrangements had been made for ıe April meeting in which the sound stem of Robert Fine, PerspectaSound, ill be presented. Tentative plans were lso discussed for the May meeting. The oard also discussed a proposal to adopt a road long range plan or theme for the ıture programs of the Section. It was ointed out that such a proposal would in self help all the members of the Board to btain suitable papers by directing our ıinking and inquiries. A decision on this ıatter was deferred.

At a section meeting on Wednesday, Iarch 24, Stanley Powers of the Densitometer Control Center, Color Technology Div., Eastman Kodak Co., presented a aper "A Chi Square Method for Controlling One or More Instruments or Processes." Mr. Powers pointed out that any ıdustrial process had to be in control if it as to be profitable. Referring to the olor densitometers used by the Eastman Kodak Co., Mr. Powers pointed out that ıasmuch as these instruments were effecively the "yardstick" by which the maerials or processes were measured, it was ighly desirable that the various groups oncerned have a uniform "yardstick." he development of the system of control hich is applied to these instruments was xplained in detail. The step-by-step rocedure for establishing a control system as outlined. Following the paper there as an active discussion period. The aplication of these principles to one or more ıstruments was explored and the advanages to be gained by standardization were ressed.—*C. W. Seager*, Manager, Atlantic Coast Section, c/o Ansco, 405 Lexington ve., New York 17.

Book Reviews

Drive-In Theatre (A Manual of Design and Operation)

y George M. Petersen. Published (1953) y Associated Publications, Kansas City, Mo. 226 pp. + 76 illus. Paper covered × 9 in. Price $3.00

Mr. Petersen offers some timely advice on all phases of construction and operation for both prospective exhibitors and those who are now operating drive-in theaters. Among the many topics covered are site selection and design, financing, materials and construction, landscaping, lighting, drainage, sewage disposal, promotion, advertising, concessions, maintenance and insurance. In discussing each topic, the author is careful to present the methods and practices which he has found to be successful during his 14 years of experience with hundreds of drive-ins in the United States, Canada and Hawaii. The point emphasized early in the discussion is that, because the drive-in field is relatively new, advice by experts with considerable experience can help the new exhibitor to avoid initial costly mistakes.

Mr. Petersen's thesis is that success or failure is largely determined by the care given to the numerous details of the complicated business of building and operating a theater; and his coverage is consistent with this thesis. For example, in the chapter dealing with concessions, he goes to the extent of offering a special recipe for chili sauce. There are numerous diagrams, illustrative examples, and tables showing how to estimate floor space, costs, concessions and other facilities for a given number of cars. Of special interest to operators of existing establishments are the chapters describing profitable promotional schemes, and the techniques of handling concessions of many kinds including the increasingly popular "kiddylands." Considerable space is devoted to what might be classed as "pep talks" for the operating personnel.

The entire book is written in a straightforward, factual style, convincing in its thoroughness, and directed toward expounding those factors which constitute honest showmanship and form the basis of a sound business enterprise. The broad principles of pleasing the patron, as presented by the author, are not limited to the drive-in theater.

Some of the content of the book has appeared previously in the *Modern Theatre* section of *Boxoffice*. The book as a whole is well unified, and is not a mere collection of separate articles.—*Rowland H. Müller*, General Precision Laboratory Inc., Pleasantville, N. Y.

Sound Film Projection, Fourth Edition

Edited by E. Molloy; Contributors, F. W. Campbell, T. A. Law, L. F. Morris and A. T. Sinclair. Published (1951) by George Newnes, Ltd., Tower House, Southampton St., London, W.C.2. i–vii + 330 pp. + 8 pp. index. 228 illus. 6 × 9 in. Price 30 shillings ($4.20) net.

For readers in this country, the chief value of the book is as a reference source of general background interest. Material on installation, maintenance, trouble shooting ("fault tracing") and repair is presented with a touch that reveals much practical experience, and sympathy with the plight of the novice who has to be shown exactly how something is done. Since all the projectors, and most of the soundheads and amplifiers are of English origin, little of this operating information is directly usable, other than as a basis for comparison against our own practices. For example, one gathers that some of the service operations with which a British projectionist must be familiar are not the normal duties of a projectionist in this country; and this difference may be of interest. Technical descriptions of design features not commonly encountered here are clearly presented and well illustrated.

Systems of sound-film projection dealt with in detail are: R.C.A. Photophone, Gaumont-Kalee and British Acoustic, British Thomson-Houston, and Western Electric. Sound-reinforcement equipment and public-address systems are reviewed. There is a chapter on theater television, but the information is necessarily earlier than the publication date of the book.—*Willy Borberg*, General Precision Laboratory Inc., Pleasantville, N. Y.

Theatre Catalog, 11th Annual Edition, 1953-1954

Published (1953) by Jay Emanuel Publications, Inc., 246–48 N. Clarion St., Philadelphia 7. i–xxxii + 379 pp. Profusely illus., includes advtg. $9\frac{1}{4}$ × $12\frac{1}{4}$ in. Price $5.00 (foreign shipments $10.00 a copy).

Theatre Catalog is an impressive yearbook on theater construction, design, maintenance, operation and advertising. Everything from acoustics to television is covered in this year's issue. Comprising a collection of articles by leaders in their respective fields, the catalog is divided into three books: (1) Design and Construction, (2) Equipment, and (3) Management. The first book covers design, construction and drive-in theaters, and is profusely illustrated with almost 200 photos. A complete listing of all operating drive-ins in the U.S. is also included. The second book contains articles on signs and marquees, snow-melting sidewalks, new projection and sound-equipment techniques for 3-D, wide-screen, stereosound, etc., and installation and maintenance information on seating, flooring, and carpeting. Of particular interest is an article by SMPTE President Herbert Barnett describing and evaluating the various new projection and sound systems recently developed for the industry. The third book contains articles on promotion and management, parking problems, advertising and theater television. An editorial feature describes and illustrates the work of theater architect Ben Schlanger. There is a complete subject index to the present issue of the catalog as well as a cumulative index to all previous editions.—*Rowland H. Müller*, General Precision Laboratory, Inc., Pleasantville, N. Y.

Farbenmetrik

By Dr. Hans Arens. Published (1951) by Akademie-Verlag GmbH., Berlin NW7, Schiffbauerdamm 19. 68 pp. + 8 pp. glossary + 3 pp. index. 38 illus. $6\frac{3}{4}$ × $9\frac{3}{4}$ in. $3.31.

This book is a short survey of color with special reference to color measurement. The purpose of the book, and of others in a projected series of small books, is to supply a need for technical background information among those concerned with the numerous applications of color photography.

Most of *Farbenmetrik* divides into two parts, the first of which is concerned with the characteristics of color. Color is considered both from the perceptual point of view and the physical or stimulus standpoint. The perceptual development is strictly according to Hering and Ostwald. The four primary colors, red, yellow, green and blue (Urfarben), together with black and white in appropriate mixtures yield all colors. The mixture with black and white corresponds to the achromatic component in most perceived colors. These colors of varying lightness and saturation are known as white-, black- and gray-veiled ("verhüllt") colors. The discussion of color from the stimulus standpoint purports to deal with the physical correlates of this color-veiling.

The second part of the book treats more directly of color measurement; but as before the topic is broken down into stimulus and response aspects. Following an introduction to such familiar fundamentals as spectrophotometric curves, Grassmann's laws, vectorial representations and transformations of systems, there is a detailed treatment of the Luther color moment and solid. This ties in with Ostwald and according to the author affords the best approach to color measurement congruent with perceived color. Evaluations of color-veiling, color thresholds and color differences are briefly considered; and finally some of the methods of establishing functional relations between perceptual and psychophysical color systems are mentioned.

Granted that a satisfactory survey of color in the compass of 76 pages is a formidable task, the results are disappointing. The sources of material consulted were apparently very limited; Judd and Munsell are scarcely mentioned despite the author's evident interest in color appearance. Little or no account is taken of numerous investigations and topics of obvious relevance. Furthermore and contrary to reasonable expectation, the subject matter of color has not been especially related to color photography. There are also terminological difficulties such as the continued use of the term "Helligkeit" to indicate either brightness or luminance. Such shortcomings should not be blamed on the author; for the book happened to appear just as many changes in the German nomenclature were being put into effect. It is apparent, however, that this publication cannot be strongly recommended to the uninformed reader to whom it is largely addressed.

On the other hand, there are a number of favorable features. Among these may be mentioned excellent examples in the introduction illustrating color principles, an effort toward a stimulus-response organization of the subject matter, a critical statement of the principle of additivity of luminance, a discussion of Luther's moment which may interest the expert, and a technical glossary of 90 items. The desirability or undesirability of the author's general position may be left up to the reader. This is that visual colorimetrics are more valuable and important for color photography than is conventional colorimetry.

Günter Wyszecki contributed substantially to this review by reading the book and making his comments freely available.—*Sidney M. Newhall*, Eastman Kodak Co., Rochester 4, N.Y.

French Film

By Georges Sadoul. Published (1953) by the Falcon Press (London) Ltd. Distributed in the U.S. by The British Book Centre, Inc., 122 E. 55 St., New York 22. 131 pp. Illus. Subject Index. $7\frac{1}{2} \times 10$ in. $3.50.

The considerable public in this country that frequents French films will be extremely interested in this little book. Beginning with the early contributions of France to the development of motion-picture equipment, and the professional controversies between Lumière and Melies, the author follows the ups and downs of French film production over the years.

Beset by financial troubles and difficulties in obtaining equipment tied up by foreign patents, the French motion-picture industry, like that of Europe generally, has had to depend on a minimum of material and a maximum outlay of ingenuity. Following Rene Clair's successful invasion of world markets in the early 30's a handful of brilliant directors have given the French film an enviable reputation for artistic and technical merit. Their work is briefly but comprehensively reviewed in these pages, accompanied by a good selection of stills; and the consequent listing of pictures, with brief descriptions, makes an excellent guide to the major French productions.—*D.C.*

Motion-Picture Catalogs

Motion pictures, from the *Edison Kinetoscope Record of the Sneeze*, more frequently referred to as *Fred Ott's Sneeze*, produced in 1894, to such films as *She Wore a Yellow Ribbon*, produced in 1949, are listed in three catalogs issued by the Library of Congress. Two of the volumes—*Motion Pictures,* *1894–1912* and *Motion Pictures, 1940–1949*—have just been published and they, together with *Motion Pictures, 1912–1939*, issued in 1951, provide an unbroken, 55-year record of the copyright registration of more than 76,000 motion pictures in this country. Foreign films registered for United States copyright are also listed.

The content of the various entries differs slightly because of changes in the copyright laws, requirements and procedures over the years, but the entry for each film usually includes the title, date, producing company, facts about the published work on which the film was based, and the author of the film story. Orders should be sent to the Copyright Office, Library of Congress, Washington 25, D.C. Costs are $2.00 for the 92 pp. covering 1894–1912, $18.00 for the 1250 pp. of the 1912–1939 span, and $10.00 for 598 pp. on 1939–1949.

Current Literature

The Editors present for convenient reference a list of articles dealing with subjects cognate to motion picture engineering published in a number of selected journals. Photostatic or microfilm copies of articles in magazines that are available may be obtained from The Library of Congress, Washington, D.C., or from the New York Public Library, New York, N. Y., at prevailing rates.

American Cinematographer

vol. 35, Jan. 1954

Projection Viewing With the Westrex Editer (p. 23) *L. Allen*

The Zoomar Varifocal Lens for 16mm Cameras (p. 27) *A. D. Roe*

vol. 35, Feb. 1954

New Arriflex Cameras Feature Many Improvements (p. 80) *A. Rowan*

Care and Handling of Film in the Tropics (p. 89) *J. Forbes*

British Kinematography

vol. 23, no. 6, Dec. 1953

Studio Spotlights. Summary of Tests (p. 156)

Factors Affecting 16mm Picture Illumination and Quality (p. 160) *D. S. Morfey*

Canadian Film News

October 1953

Pixilation by *Norman McLaren* (Reprinted in Rushes for Dec. 7, 1953, Film Council of America)

Proceedings of the I.R.E.

vol. 42, Jan. 1954

A Versatile Approach to the Measurement of Amplitude Distortion in Color Television (p. 240) *J. A. Bauer*

Test Instruments for Color Television (p. 247) *W. C. Morrison, K. Karstad and W. L. Behrend*

Delay Equalization in Color Television (p. 258) *G. L. Fredendall*

Alignment of a Monochrome TV Transmitter for Broadcasting NTSC Color Signals (p. 263) *J. F. Fisher*

Transmission of Color Over Inter-City Television Networks (p. 270) *J. R. Rae*

Improving the Transient Response of Television Receivers (p. 274) *J. Avins, B. Harris and J. S. Horvath*

Theory of Synchronous Demodulator as Used in NTSC Color Television Receiver (p. 284) *D. C. Livingston*

The DC Quadricorrelator: A Two-Mode Synchronization System (p. 288) *D. Richman*

Processing of the NTSC Color Signal for One-Gun Sequential Color Displays (p. 299) *B. D. Loughlin*

Compatible Color Picture Presentation With the Single Gun Tricolor Chromatron (p. 308) *J. D. Gow and R. Dorr*

Improvements in the RCA Three-Beam Shadow-Mask Color Kinescope (p. 315) *M. J. Grimes, A. C. Grimm and J. F. Wilhelm*

The CBS Colortron: A Color Picture Tube of Advanced Design (p. 326) *N. F. Fyler, W. E. Rowe and C. W. Cain*

A Laboratory Receiver for Study of the NTSC Color Television System (p. 334) *C. Masucci, J. J. Insalaco and R. Zitta*

Bibliography of Color Television Papers Published by the IRE (p. 350)

International Photographer

vol. 26, Jan. 1954

Recording TV Pictures on Magnetic Tape (p. 5)

vol. 26, Feb. 1954

Color Television (p. 5)

International Projectionist

vol. 29, Jan. 1954

1954 Seen as Biggest Year for Color (p. 7) *J. Morris*

Recent Projection Advances in Europe (p. 9) *R. A. Mitchell*

Color is Catalyst in Battle of the Tubes (p. 14) *F. Hodgson*

The 3-D Score for '54 (p. 16) *T. L. Burnside*

vol. 29, Feb. 1954

That Hardy Perennial: Damaged Film! (p. 9) *J. Morris*

Proper Tools a 3-D 'Must'. (p. 12) *S. Cohen*

Atom-Smasher Principle Aids Color TV (p. 14) *F. Hodgson*

Light Gain, Better Screens Demanded by New Systems (p. 17) *L. Satz*

Kino-Technik

vol. 8, Jan. 1954

Bedeutung und Ausführung des Tricks (p. 2) *H. Burdich*

Tier- und Pflanzenfilme auf Ferrania-Color-Material (p. 7) *G. Beissert*

Messkinematographische Aufnahmen mit dem Kurvenauswertgerät: "Messkineautograph" (p. 8)

Störungen bei der Vorführung von Tonfilmen (p. 12) *H. Tümmel*

Rundgang durch die italienischen Ateliers (p. 14) *E. Monachesi*

vol. 8, Mar. 1954

Photo-, und Film-Aufnahmeverfahren vom Luftfahrzeug aus. (p. 58) *H. Atorf*

Kino-Farbfilmaufnahmen in grösseren Meerestiefen (p. 62) *D. Rebikoff*

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The Chromatic Color Picture Tube (p. 52) *W. H. Buchsbaum*

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Fundamentals of Color TV. The NTSC System (p. 59) *M. S. Kiver*

Revue du Son

no. 4–5, July–Aug. 1953

Les microphones: principes et caractéristiques des divers types (p. 147) *R. Lehmann*

Le controle électro-acoustique au cinéma. Essais sur films (p. 171) *C. Soulé*

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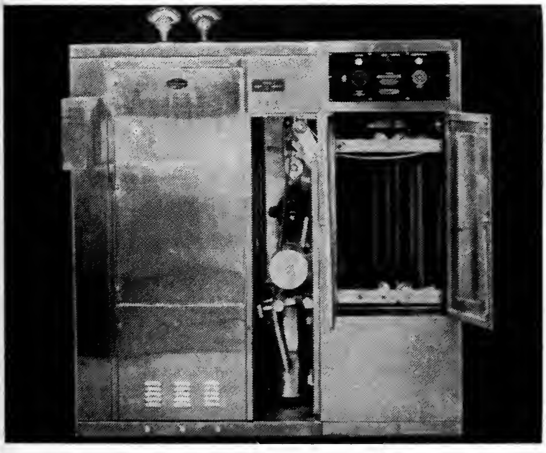
Les microphones: principes et caractéristiques des divers types (p. 193) *R. Lehmann*

La production des films en stéréophonie (p. 207) *L. Martin*

Un second amplificateur "son" pour la télévision (p. 217) *L. Chrétien*

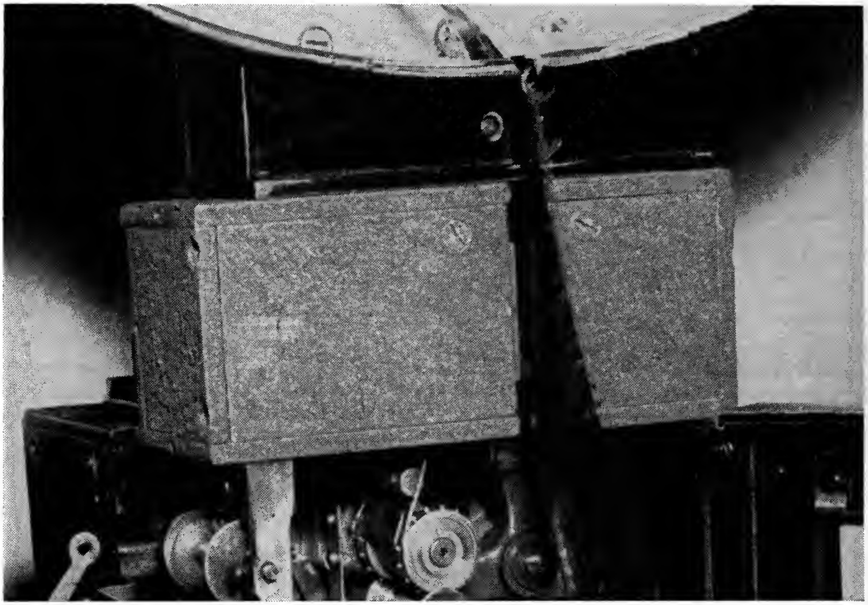
New Products

Further information about these items can be obtained direct from the addresses given. As in the case of technical papers, the Society is not responsible for manufacturers' statements, and publication of these items does not constitute endorsement of the products.



A new multipurpose film processor for 16mm, 35mm or 70mm film is announced by the Oscar Fisher Co., Peekskill, N.Y. The processor is designed for daylight operation and will process films of any length, perforated or unperforated.

Specifications are: dimensions 7 ft × 24½ in. × 7 ft high; processing speed adjustable from 1 fpm to 50 fpm; jet spray system; recirculation of 5 gal per chemical bath with automatic replenishment; stainless steel cabinet; adjustable thermostatic temperature controls to 120°; Fisher Anhydrator system of heatless drying; 290 ft of film or leader required for machine capacity; operates on standard 110-v, 60-cycle line, 1500-w maximum load. By addition of extra "wet" cabinets either reversal or color films can be processed.

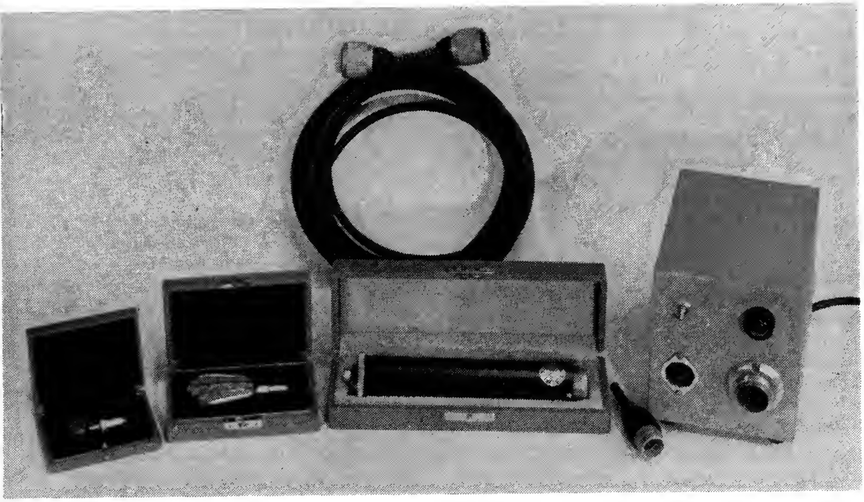


Panaphonic sound is a new low-cost stereophonic sound system developed by Dorsett Laboratories, Inc., Norman, Okla. The equipment operates on a binary signal system from darkened intersprocket spaces at both edges of the film, sensed by two small photocells whose amplified outputs operate relay tubes to provide four loudspeaker combinations — center, right or left horns, and all speakers including side and rear of the auditorium. The system is designed to be compatible with present sound systems and does not affect picture projection.

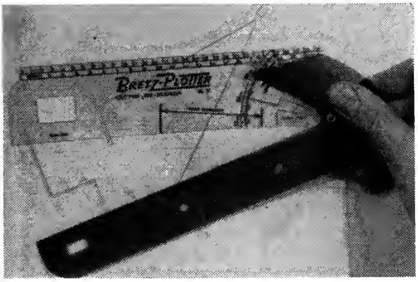
The cue lead is adjusted by the timing circuit to conform to all types of projectors which are currently used. An integrating circuit together with the filter also serves to eliminate spurious cues due to film splices or other causes. In order to permit addition of cue marks to prints already in release, a special automatic cuing machine has been developed which applies a dye to the intersprocket spaces, dries it and rewinds the takeup reel. In the case of new prints, the cue marks can, of course, be darkened photographically.

A new drive-in theater stereophonic sound system has been demonstrated by Dorsett Laboratories, Inc., Norman, Okla., avoiding the use of multiple audio circuits and a plurality of audio amplifiers. The signals from the soundtracks are picked up and amplified in the usual single high-powered audio amplifier used in all drive-in theaters. In addition, certain control signals are picked up from the film or otherwise introduced. The loudspeaker to go in the automobile consists of three small dynamic loudspeakers installed in a single enclosure and alternately or simultaneously connected to the output of the single audio amplifier through a suitable relay controlled by the directive effect control signals. By this means signals from the soundtrack can be directed to the center speaker for dialog, to the left speaker for left screen sounds, to the right speaker for right screen sounds, or to all speakers simultaneously for surround effects. The new speakers may also be used with three-circuit stereophonic systems by adding another pair of wires. These may be combined with the existing audio pair to provide three audio circuits; four wires with one a common return. In this case, three separate channels and amplifiers are used, as in regular stereophonic sound.

The Schall-Technik Condenser Microphone CM 51, with power supply, is distributed here by Reeves Equipment Corp., 10 E. 52 St., New York 22. Frequency response is claimed to be uniform throughout the range of 30–18,000 cycles, and transient oscillations to be absent. Its construction is designed to make it insensitive to moisture, temperature and mechanical accelerations. Two pickup patterns are available, cardioid and nondirectional. The head capsules for each pattern are plug-in and can be purchased separately. The high output of this system permits operation at considerable dis-



tances from the mixer without impairing the frequency response and with freedom from inductive pickup in the cables.



The Bretz-Plotter, described as "the TV director's slide rule," is a new shot-plotter for laying out a new set or new camera placements. It can be used to measure angles, distance from camera, height of scene, or size of sets or props, and to indicate horizontal angle of view of all TV lenses, range of principal Zoom lenses, maximum and minimum extensions of mike boom, and vertical angles of view of standard lenses. The plotter is designed to help in determining the lens required for a given shot, the camera position required, the shot resulting from given camera position and lens, the position of mike boom base, and the height of shot at any distance from the camera. The price is $3.00, or $2.50 apiece for quantities of 10 or more, available from Rudy Bretz, Television Consultant, Park Trail, Croton-on-Hudson, N.Y.

Employment Service

These notices are published for the service of the membership and the field. They are inserted for three months, at no charge to the member. The Society's address cannot be used for replies.

Positions Wanted

Motion-Picture Television Technician: 10 yr intensive skill and know-how related to 16-35mm cinematography, animation, recording (optical, tape, disk), editing, laboratory processing practice (black-and-white, color); also kinescope recording techniques; self-reliant; inventive; relocate if required; write: CMC, c/o Penning, 435 E. 74th St., New York 21, N.Y.

Electronics Engineer: B.S.E.E., 3 yrs chemical engineering, 2 yrs graduate work in physics. Currently working on Masters Degree. Engaged in gaseous electronics research, experienced in design and development of electronic instrumentation, installation and operation of automatic recording temperature control systems, vacuum system technique, maintenance and repair of all types of electronic equipment. 4 yrs retail business experience. Possess ability to write clear, concise reports. Interested in the motion picture, both artistically and technically. Desire position with organization in Los Angeles area preferably engaged in motion-picture production. Expect to be in Los Angeles area in late summer this year. Request interview. Member, IRE, SMPTE, Fla. & Nat. Soc. of Prof. Engs. Registered Engineer in Training State of Florida. Age, 28; unmarried. Write: Berel David Solomon, Box 274, Univ. Station, Miami, Fla.

Motion-Picture Producer-Director: Now employed in charge of motion-picture production for leading oil company. 18 yrs experience in production, script, direction, motion-picture photography, editing, scoring and recording of industrial, sales training, educational, travel and theatrical motion pictures. Highly experienced in low budget productions for industry. Available in near future; employer has been notified of desire for change to better position. Address inquiries to: A. P. Tyler, Box 2180, Houston, Tex.

Motion-Picture Cameraman: Wants position assisting editor or with production crew. College graduate, film production major, production experience prior to entering Service. Army cameraman for 2 yr in Arctic. Separation from Army July 16, 1954. Will consider temporary position and/or travel. Write Elliott H. Butler, 470 Audubon Ave., New York 33.

Motion-Picture Cameraman, Film Editor: 15 yrs experience all phases of motion-picture work, including research; 3 yrs TV film operations. Developer of Panoramascope wide-screen motion-picture system. Active Member of SMPTE. Desires position with industrial or educational film producer as first cameraman or film editor. Wire: Frank E. Sherry, Jr., 207 West Rusk St., Tyler, Tex.

Positions Available

Motion-Picture Sound Mixer (male), GS-10: Require $5\frac{1}{2}$ yr experience in sound mixing for radio, disk recording and motion-picture production, of which at least 3 yr must have been in mixing for motion-picture production, include experience with live dialogue, narration, music, sound effects, lip synchronization and re-recordings. $5500/yr. Obtain Form SF 57 at any first class Post Office or Government Agency; forward or deliver completed to Civilian Personnel Div., Signal Corps Pictorial Center, 35-11 35 Ave., Long Island City, N.Y.

Motion-Picture Asst. Director (male), GS-10: Require $5\frac{1}{2}$ yr progressively responsible experience in motion pictures, theatrical, television broadcast or radio broadcast production which has demonstrated the ability to perform in this position. Included in general experience must be at least $2\frac{1}{2}$ yr experience as a first assistant director in motion-picture production. $5500/yr. Obtain Form SF 57 at any first class Post Office or Government Agency; forward or deliver completed to Civilian Personnel Div., Signal Corps Pictorial Center, 35-11 35 Ave., Long Island City, N.Y.

Chicago Film Studio needs man to take charge stop-motion and animation dept. Must be experienced, able to direct title and animation cameramen. Write giving experience and salary desired. Filmack Corp., 1327 S. Wabash Ave., Chicago 5, Ill.

Meetings

Society of Photographic Engineers, Fourth Annual Conference, May 26–28, U.S. Hotel Thayer, U.S. Military Academy, West Point, N.Y. Some 35 titles have been scheduled. For information write: Anthony E. Salerno, c/o Pavelle Color, Inc., 533 W. 57 St., New York 19.

Society of Motion Picture and Television Engineers, Central Section (with Western Society of Engineers), June 10

American Institute of Electrical Engineers, Summer General Meeting, June 21–25, Los Angeles, Calif.

Acoustical Society of America, June 22–26, Hotel Statler, New York

American Physical Society, June 28–30, University of Minnesota, Minneapolis, Minn.

American Physical Society, July 7–10, University of Washington, Seattle, Wash.

National Audio-Visual Convention and Trade Show, Aug. 1–4, Conrad Hilton Hotel, Chicago.

Biological Photographic Association, Annual Meeting, Aug. 25–27, Chalfonte-Haddon Hall, Atlantic City.

Illuminating Engineering Society, National Technical Conference, Sept. 12–16, Chalfonte-Haddon Hall, Atlantic City, N.J.

2d International Symposium on High-Speed Photography, Paris, September 22–28, 1954. Arranged by the Association Française des Ingénieurs et Techniciens du Cinéma. Applications or inquiries should be addressed to the Secretary of the Organizing Committee, P. Naslin, Laboratoire Central de l'Armement, Fort de Montrouge, Arceuil (Seine), France.

National Electronics Conference, Tenth Annual Conference, Oct. 4–6, Hotel Sherman, Chicago.

Photographic Society of America, Annual Meeting, Oct. 5–9, Drake Hotel, Chicago, Ill.

American Institute of Electrical Engineers, Fall General Meeting, Oct. 11–15, Chicago, Ill.

76th Semiannual Convention of the SMPTE, Oct. 18–22, Ambassador Hotel, Los Angeles

77th Semiannual Convention of the SMPTE, Apr. 17–22, 1955 (next year), Drake Hotel, Chicago

The International Commission on Illumination is to hold its next international conference in Zürich, Switzerland, June 13–22, 1955 (*next year*). Offers of papers should be addressed to the Chairman of the Papers Committee (A. A. Brainerd), 1015 Chestnut St., Philadelphia 7. Manuscripts must be in the hands of the Central Bureau between Oct. 1 and Dec. 31, 1954.

78th Semiannual Convention of the SMPTE, Oct. 3–7, 1955 (next year), Lake Placid Club, Essex County, N.Y.

Photographic Society of America, 1955 Convention, Oct. 5–8, 1955, Sheraton-Plaza Hotel, Boston, Mass.

Magnetically Striped Loops for Lip-Synchronizing Production

By GEORGE LEWIN

A new system for lip synchronizing has been designed by the Signal Corps Pictorial Center, using a magnetic stripe on the composite print from which the individual loops are made. This permits immediate synchronous playbacks with any length of loop, so that corrections can be made on the spot. The need for subsequent editing is thereby reduced or may be eliminated entirely. By reassembling the recorded loops into a complete reel, it is possible to eliminate all photographic raw stock and processing except for the final release negative, thereby achieving great economies in film consumption and editorial costs. Furthermore, since the projector becomes a recording machine as well, the regular recording equipment is released for other work.

At the May 1951 Convention of this Society, the author presented a paper on various innovations in the use of magnetic recording for motion-picture production.[1] One of the systems described as being under development at that time was the use of loops of 35mm magnetic film, cut to the exact length of the picture loop, so that synchronous playbacks could be made. This system worked out very well and has been in regular use for almost two years, in spite of the disadvantage of the extra work involved in cutting loops to an exact length.

In actual practice it developed that the most practical procedure was to standardize on two loop lengths, 25 ft and 40 ft. All shorter loops are built up to 25 ft by adding leader, and all loops above this length are built up to 40 ft. In this way it is possible to achieve practically continuous operation by using two loop recorders, and switching from one to the other whenever necessary. It is never necessary to unthread the loops, as the selected takes are transferred immediately to film.

The principal disadvantage of this system is that it ties up two magnetic recorders, besides restricting the length of loop to only two sizes. In order to overcome both these disadvantages, the system to be described in this paper was devised.

New System

The new system makes use of a magnetic stripe, 110 mils wide, placed on the composite workprint prior to breaking

Presented on October 6, 1953, at the Society's Convention at New York by George Lewin, Chief, Sound Branch, Signal Corps Pictorial Center, 35-11 35 Ave., Long Island City 1, N.Y. (This paper was first received October 1, 1953, and in revised form January 8, 1954.)

it down into loops. This stripe is placed so that it starts at the center line of the photographic soundtrack and extends inward toward the picture area, into which it encroaches very slightly. The width of 110 mils was selected as probably the minimum width for satisfactory signal-to-noise ratio. Starting at the center line, of course, leaves one-half of the photographic track available for cuing purposes.

The first problem was suitable mounting of the record head in the projector, and since the soundheads were RCA, and an RCA mounting kit for a reproduce head was already available, this was selected for the initial installation. Fortunately, this head is designed for both recording and reproducing, which fitted into our plans, since a separate reproduce head would throw the playback out of synchronism.

A requirement which we imposed on ourselves was that the system should be capable of continuous operation — that is, as soon as one loop was approved, it should be possible immediately to start rehearsing the next one even while the first one was being transferred to film. This, of course, meant duplicate installations on two projectors, and a rather elaborate switching system which will be described below. The reason for stressing the importance of continuous operation is that since the use of playbacks obviously takes extra time, it is imperative to eliminate any other delays in the operation.

Another requirement is a satisfactory splice. It is often necessary to have the sound begin at the very first frame of picture which means that the sound must begin in the leader and continue across the splice. Fairly good results were obtained using the electrical butt-weld type of splice,[2] but there was still room for improvement. A diagonal splice was considered but was discarded since no satisfactory diagonal butt-weld splicer was immediately available. Besides, it was felt the diagonal splice might lead to confusion in accurate editing of the film.

A rather novel solution to the splicing problem was finally adopted which turned out to have other important advantages as well. Instead of using a diagonal splice, the magnetic head itself is turned at an angle, which has the same effect in reducing the splice noise. Of course, this puts the modulation on a bias which makes it impossible to play the tracks on conventional reproducers, but this is not a serious drawback since the track is immediately transferred to photofilm. The standard butt-weld splicer is entirely satisfactory with this system.

One of the unexpected advantages of the diagonal arrangement is that it permits the use of the full 200-mil gap even though the stripe is only 110 mils wide. By actual measurement, the level output from the head is at least 3 db higher by this arrangement. The other advantage arises from the fact that the edges of the stripe are not always very uniform and considerable extraneous noise is generated if the head scans the edges. The diagonal arrangement eliminates this effect and at the same time increases the level output, whereas if a straight head were cut down to miss the edges, there would probably be a reduction in output.

The angle of bias is set at 60° with respect to the conventional position, which allows the full 200-mil gap width to be used while requiring only 100 mils of stripe width. It is to be expected, of course, that the angular arrangement will cause a greater gap loss at the higher frequencies. Actual measurement showed this loss to be 6 db at 8000 cycles, which is easily compensated by equalization without appreciable penalty in noise level.

Figure 1 shows the installed head. It is to be noted that this installation requires the stripe to be placed on the emulsion side of the film and early tests indicated that the stripe is quite satis-

Fig. 1. Record-playback head installed in projector. Note angular position of head.

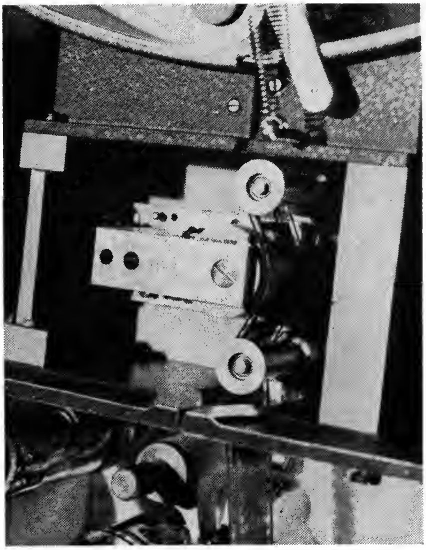


Fig. 2. Erase head installed between picture head and upper magazine.

factory in this position, although the base side is to be preferred. However, it was not felt expedient to attempt to redesign a head mount to permit use of the base side before some practical experience was obtained in the use of the system. Besides, in the continual quest for means of speeding up the operation of the new system from a production point of view, another idea suggested itself which not only insured faster operation but also permitted use of the base side for the stripe without the need of extensive redesign of the head mount.

It was felt that a justified objection from a production point of view would be the delay involved in waiting for a print to be sent out for striping, before work could proceed. This could be avoided if raw stock were available with the stripe already on it. Then the prints would be ready for breakdown into loops as soon as they were received from the laboratory, just as in conventional practice. Successful striping of raw stock must be done on the base side, since the emulsion swells during processing and would destroy the stripe. Then, in order to have the stripe contact the head with the present design, it is only necessary to print the film through the base rather than by emulsion-to-emulsion contact. The print is then projected with the emulsion toward the screen and the stripe will contact the head. In other words, we have made the film fit our particular projector layout by printing it accordingly. There is a very slight loss in detail in both picture and soundtrack due to printing through the base, and a slight additional out-of-focus effect in the sound reproduction, but since these affect only the workprint and not the finished product, they are not deemed important.

Figure 2 shows the installation of the erase head. As may be seen, this is installed above the picture head in order to avoid extensive redesign of the soundhead. Here, again, we made use of equipment already available, viz., the Westrex erase head which is enclosed in a convenient mounting. We also made use of the Westrex Oscillator, Record

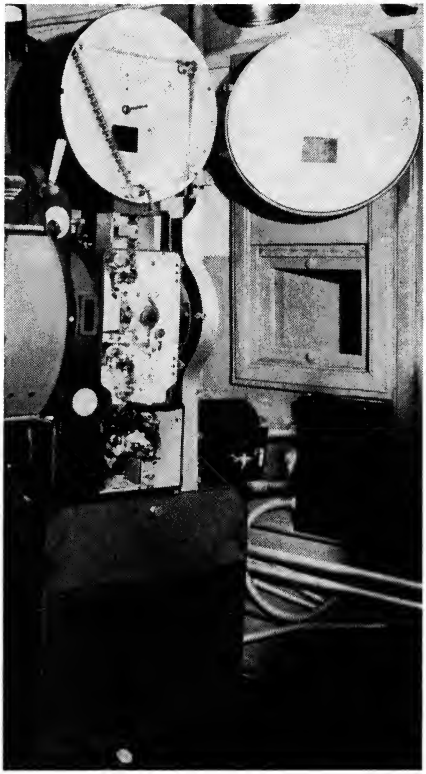


Fig. 3. Projector equipped with loop magazine and film chute.

and Playback Amplifiers. It was found that removal of the 180-ohm input termination normally used on the Westrex playback amplifier automatically provided most of the high-frequency boost required to compensate for the loss due to the angular head position.

Figure 3 shows the entire projector equipped with the loop magazine and film chutes which were designed at the Signal Corps Pictorial Center. The loop magazine is worthy of special mention as five of them have been in successful operation for over three years. It permits the use of conventionally spliced loops, wound into a small roll and eliminates the need for loop-trees. The roll is simply dropped into the magazine after unwinding enough to thread the projector. The roll unwinds itself as the projector starts up and the loose film remains in the magazine without further attention. Loops up to 200 ft in length may be used. We feel this method is superior to those used in certain other studios which require splicing from the inside to the outside of an open roll, and which require special mountings for winding and take-up of the loops. These special loops also have to be handled and stored on special racks; whereas ours can be wound into small rolls and stored in regular film cans.

A special flange was designed to facilitate the winding of our loops. This is shown in Fig. 4 with the beginning of a loop about to be wound. Figure 5 shows the loop completely wound.

A special loop separator was designed to fit into a regular film can to protect the loops against damage which would result from packing them too tightly.

Fig. 4. Special flange for winding loops.

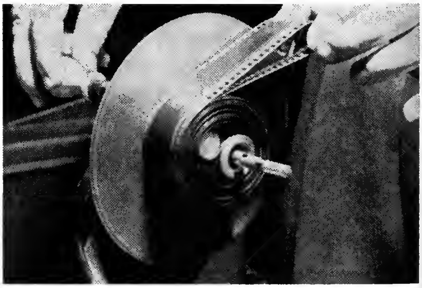


Fig. 5. Film loop completely wound.

Figure 6 shows a film can fitted with the separator and holding 12 loops. The loops can be up to 50 ft in length without undue crowding.

Operating Procedure

When a particular project is selected for lip-synchronous operation, a composite workprint on striped stock is ordered, printed through the base as just described. Additional footage is ordered printed from a negative loop of leader stock. This leader is used in each loop to provide cue marks for the actors and to permit the recording of identifying announcements. In cases where sound starts on the first frame of picture, the sound will be recorded on the last 20 frames of this leader as mentioned previously.

The sequences to be lip synchronized are then broken down into loops, using any lengths desired, as dictated by experience. The leader is spliced into each loop, using the butt-weld splicer.

Figure 7 shows the mixer's control board on which are most of the controls referred to below.

The first two loops are threaded on the two projectors and the first one started up. The mixer throws his record-playback key into record position and rehearsals begin. The photographic cue track is heard over a loudspeaker by both director and actors. When the director feels they are ready for a "take" he pushes a button which shuts off the

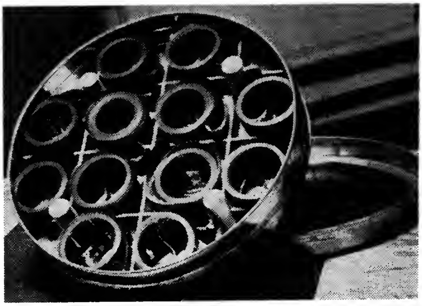


Fig. 6. Film can with separator for loops.

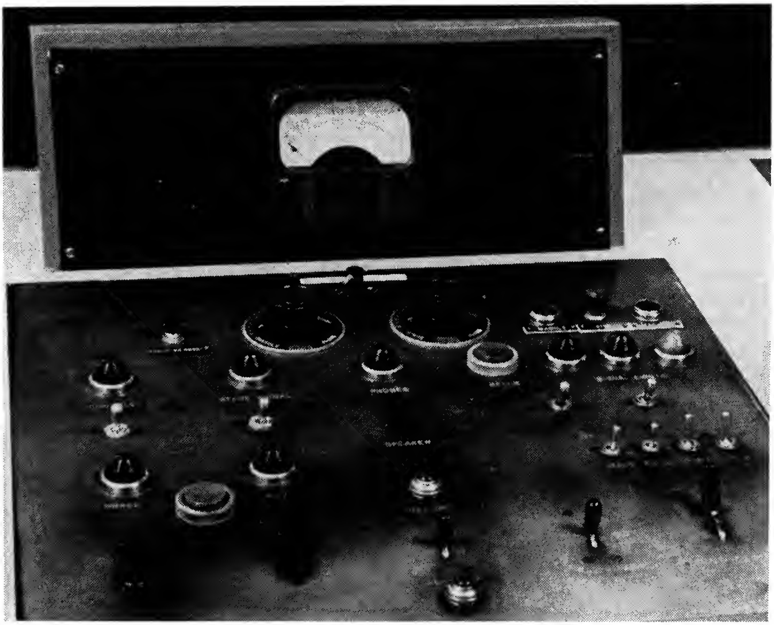


Fig. 7. Mixer's control board.

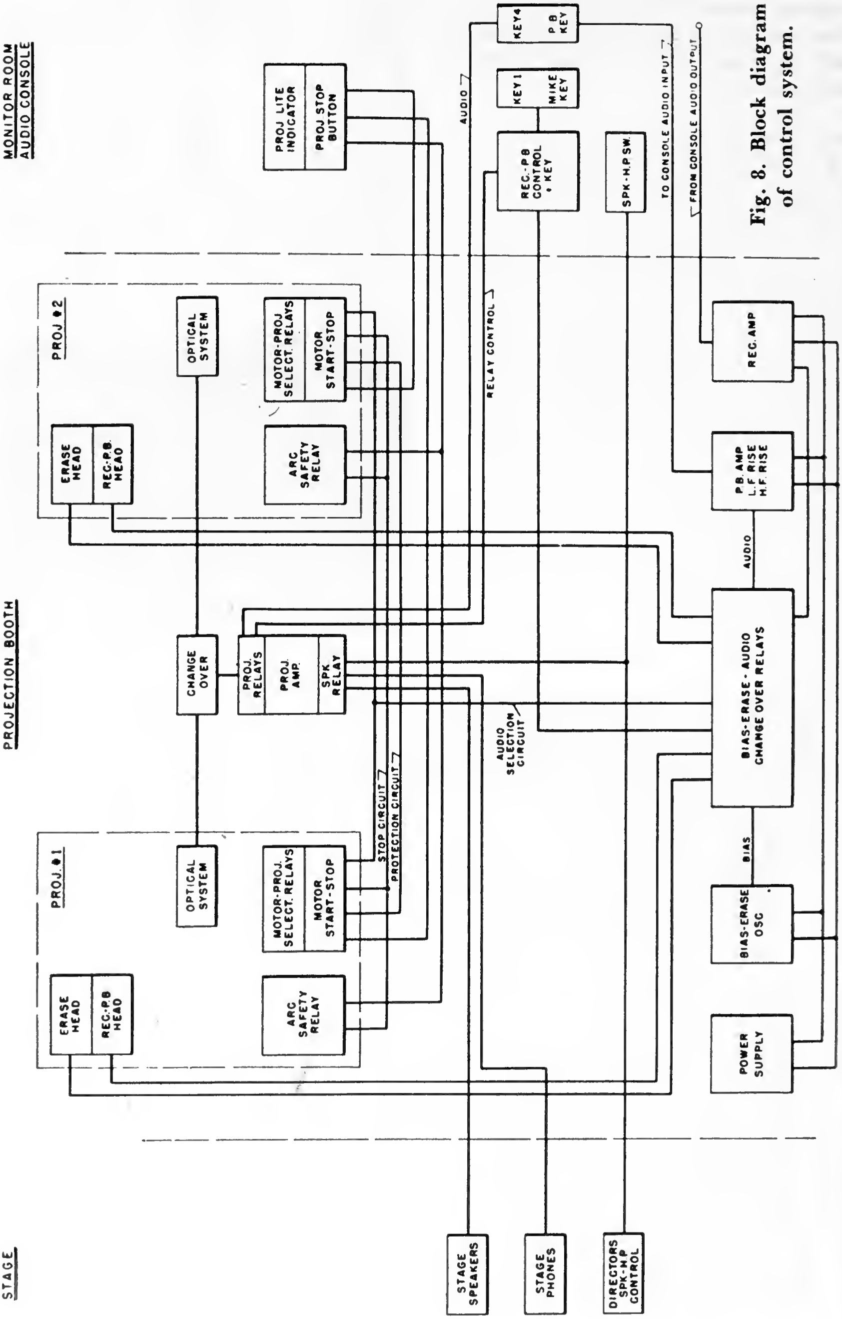


Fig. 8. Block diagram of control system.

loudspeaker and transfers the cue track to the director's headphones. Repeated takes are made until he feels he has a good one. He then calls "playback" and turns on the loudspeaker. The mixer throws his switch to "playback" and everyone hears the playback in synchronism with the picture as many times as necessary to evaluate it properly.

If the take is not good, a retake is immediately made by the same procedure. If the take is good, the director calls "print" and the projectionist takes that as the cue to start the second loop, on which rehearsals immediately start, with the cue track. He keeps the first loop running but with the arc lamp turned off. This actuates a relay which gives the mixer control of a switch which can stop the projector, but cannot start it. The mixer proceeds to transfer the first loop to photofilm. He has full control of this operation without interfering in any way with the rehearsal of loop #2 which is taking place on the stage. When the transfer is complete, he stops projector #1, which is the cue for the projectionist to unthread the loop and put on loop #3.

The mixer then turns his attention to loop #2, which by now is probably ready for a take. In this way continuous operation is possible.

Additional Features

Several other features of the switching system which are essential for smooth operation should be mentioned at this point.

Figure 8 is a block diagram of the essential components of the system.

In order to keep the number of switching operations down to a minimum, only one recording-and-playback channel is used for both projectors. Whichever projector starts up first, operates a relay which connects its head to the channel. This relay will remain in this position until the projector is stopped, at which time it automatically switches to the other projector if it is running. In this way a single record-playback switch serves to control either projector and yet protects the loop on one projector from accidental erasure while the other one is being worked on.

The stage monitor system is connected to the cue track while recording, and, of course, to the magnetic track when playing back. However, a neutral position on the record-playback key permits the cue track to be heard again if desired without erasing the tape. A "transfer" position on the microphone key not only kills the microphone but sends the cue track out to the stage so that rehearsals can proceed while the previous loop is being transferred.

Reassembling of Loops

As the operation has been described so far, it has been assumed that each good take is transferred to film for editing in the usual way. This is the logical procedure if it is felt that additional editing may be necessary to improve the synchronism. It has always been our contention, however, that if a little extra time is spent during the recording session to achieve the best possible synchronism, it should not be necessary to do any further editing. In that case, it should be possible simply to reassemble the loops into one continuous sequence and thereby have a complete soundtrack ready for the final re-recording without the need of using any raw stock or processing. The only additional precaution to be taken is that in reassembling the loops the sound takes precedence over the picture. This means that the loops will be cut open in the leader usually at least 20 frames ahead of the first frame of picture. At the tail end of the loop, the cut will probably be 20 frames ahead of the last frame of picture, at which point it would be spliced to the leader of the following loop, etc. Sequences which are covered by narration could be recorded directly on the striped film if there is no overlap. The complete roll would then be re-

Fig. 9. Spring-loaded roller installed to add tension to film.

recorded from the projector to a standard magnetic track which would then be used for the final re-recording job.

An additional technical problem arises as a result of reassembling the loops into one continuous roll. This is the requirement that the two projectors match each other very closely in azimuth and level. This problem is not serious as long as we transfer each loop immediately from the same projector on which it was recorded, but the moment we intercut, then azimuth and level differences become accentuated. The problem is aggravated by the fact that we use the same recording-and-playback amplifier for both projectors, in the interest of simplicity, and consequently it is not feasible to adjust bias current, level and equalization individually for each projector. However, by careful selection and adjustment of the heads we have succeeded in matching the projectors within ±2 db in both level and frequency response at 100 to 7000 cycles.

Mechanical Problems

The use of a 60° rotation of the magnetic head from its conventional position also introduced mechanical problems. The head mount had to be modified so that the plane of the gap is always parallel to the plane of the film. Otherwise the head contact would change while adjusting the azimuth. It was also found that the end of the head had a tendency to dig into the film, and would chip off tiny bits of emulsion which became encrusted on the head and built up until contact was lost. This was solved by lapping away some of the iron on each side of the gap so that very little metal other than the gap itself contacted the film. The leading edge of the gap was also rounded off so that it would not dig into the emulsion. These modifications did not appear to alter the magnetic characteristics of the head.

Another modification found necessary was the addition of a spring-loaded roller to put a slight tension in the film to improve the head contact. This is seen in Fig. 9. This unfortunately increases the flutter slightly, but not enough to be objectionable for voice recording.

Some hum pickup was encountered which was found to originate in the arc-lamp supply rectifiers. This was corrected by moving these rectifiers to a point just outside the projection booth. This not only eliminated the hum but cleared some extra floor space as well.

When the use of this system becomes more firmly established through practical experience, it is our intention to design a complete film-driven unit to be installed above the picture head where the erase head only is now located.

In conclusion, it is desired to express appreciation to the personnel who were responsible for most of the design; especially to James J. Kennedy, Jr., Chief of Transmission Section, and his staff, who worked out all the electrical

details; and to Stephen Szeglin and Rudolph Peters who did the mechanical design on the head mounting modifications; also to W. Norman Kessel, Chief of Projection Section, who is responsible for the design of the loop magazines. Credit should also go to personnel of Foreign Adaptations Branch for their cooperation in applying the system to actual production.

References

1. George Lewin, "Special techniques in magnetic recording for motion picture production," *Jour. SMPTE, 56:* 653–671, June 1951.
2. Leonard A. Herzig, "Splicing motion picture safety film without cements or adhesives," *Jour. SMPTE, 60:* 181–188, Feb. 1953.

Discussion

Edgar A. Schuller (Central Service Studios, Inc.): I believe you stated that the loops used at SCPC are stored as rolls. Are they stored on reels or cores? And how do you wind them without damaging the film?

Mr. Lewin: We have a little special flange which grabs hold of the end of the loop while it's still stretched out or lying in the basket and then as you wind up the flange, the loop winds up in a double layer. After it's wound up to its full length, you simply slide it off the flange. In other words, when you put it into the can where it's stored, there's no flange or hub. It just supports itself. (See Figs. 4, 5 and 6.) But I would like to point out that since we started working with these magnetic loops we found that we have to be a little more careful with them than with our ordinary picture loops because of the fact that they're really the equivalent of negatives when we get through with them. That is, they have our original recording on them, which we may have spent a long time in getting properly synchronized. So we've made up these separators in the film cans so that each loop just falls into a little compartment which prevents it from unravelling and doesn't require any paper clips which can mangle the sprocket holes and possibly introduce noises into the magnetic track.

Mr. Schuller: When you thread up your projector, beyond pulling off a few feet to thread up the reproduce-record head, do you have to further unwind the loop, or do you just drop it into the lower chamber?

Mr. Lewin: You just drop the whole thing in. That's the beauty of it. The loop can be 200 ft long if necessary and yet you only unwind from the outer layer just enough film to thread around the necessary sprockets. Then the remainder of the roll, just completely wound up as it is, is dropped into the lower magazine. As the projector starts up, the loop will unwind itself and after it has made one complete revolution it's lying in the magazine in loose layers which don't scratch the film appreciably and will take care of themselves as the projector continues to run. They'll just slide around and find their own natural position and keep going as long as you please.

Mr. Schuller: What reason prompted you to standardize on the length of 25 and 40 ft for the loops?

Mr. Lewin: That was really a description of the system we're using at present. It's what I now call the old system because with the new system using the magnetic stripes we're not restricted in the length of loop; we can use any size loop we please and in that way we overcome the objection of the foreign department who complain that it slows them up if they have to cut everything exactly to the sprocket hole in 25-ft and 40-ft lengths. They can cut any size they please.

Mr. Schuller: What was the original reason?

Mr. Lewin: The original reason was—this is going back two years ago—before we had magnetic stripe, we didn't have this special projection equipment designed and we still wanted to give the foreign department facilities for immediate playback of the loop. So therefore we used a separate loop of 35mm full-width magnetic film, which carried the soundtrack. The picture loop was just picture and cue track. It had no magnetic facilities. Therefore, the playback loop had to be exactly the same length as the picture loop, otherwise as you kept going it would fall out of sync, and obviously you can't take the time to unthread a 30- or 40-ft loop every time they complete one and start running another loop which might be 35 ft long. It's just impractical. Therefore we requested them to stick to two sizes. We keep the loops threaded up all day long on two separate recorders. We just run the 25-ft machine when they have 25-ft loops and if they have to do a 40-ft loop, we just throw one machine off the line and throw the other one on, and we're ready to go with the new length. Experience has shown that the majority of loops are between 15 and 25 ft long, so that a 25-ft loop takes care of all of these. Very few loops are over 40 ft long, so these two lengths take care of practically all cases.

Mauro Zambuto (I. F. E. Studios Inc.): I understand that your striped raw stock must be printed and developed. Do you ever have any trouble with the way the striping stands up under the action of the developer chemicals or the way the bath itself reacts to the fact that you're putting some iron oxide through it?

Mr. Lewin: No, up to date we've had no complaints from the laboratory. We warned them, of course, when we started, of what we were doing, and we asked them to make any tests that they felt necessary to make sure that we were not going to spoil their developing solution and they were not going to spoil our soundtracks. So far we haven't had a single complaint. I don't think there should be any, because the magnetic material is so inert chemically it just doesn't do anything to the developer or vice versa.

Mr. Zambuto: You see, my question is based on the fact that such a thing was tried in France a couple of years ago and they had a definite oxidation of the bath. I don't know now under what conditions they did it. Is your striping absolutely normal?

Mr. Lewin: We don't ask for anything special and I might as well point out that the stripe that we're talking about here is a Reeves Soundcraft stripe and possibly somebody from that company might venture some information as to why it doesn't bother the bath, but I can testify that it hasn't bothered it as yet.

Edward Schmidt (Reeves Soundcraft): I don't know of any reason at all why the stripes should bother the bath. All sorts of tests here in the East and on the West Coast, previous papers presented before the Society describing the system used by Columbia Pictures and M-G-M, work of our own on reversal films as well as black-and-white films, even up to the point of these high-speed processing machines where the complete processing is carried out in 45 sec or so, have shown no chemical action on the bath or no effect of a prerecorded magnetic signal on the stripe by any processing we've run into.

Mr. Zambuto: Not even any damage upon the stripe because of mechanical action in consequence of shrinkage, humidity, etc.?

Mr. Schmidt: None that I've ever heard of. You see, the iron oxide particles in a good dispersion are so wrapped up in a very thin layer of inert binder, plastic-like material, that there is no way for any chemical action to reach the individual particles of the oxide.

Mr. Lewin: I'd like to remind the audience, while I still have the mike, that I have about 25 samples here that I promised to give out of the striped film in which the magnetic track has been made visible by means of iron filings. I also want to point out that I'm indebted to Mr. Walter Hicks of Reeves Sound for making these samples.

Joseph E. Aiken (Naval Photographic Center): Mr. Lewin spoke in regard to one of his systems about a 35mm projector which he caused to reverse or run backwards. I'd like to ask Mr. Lewin if any modification of the 35mm projector was necessary in order to have it back up.

Mr. Lewin: No, practically none. That's something we've been doing for well over two years now. The only modification I can recall is that we installed a Moviola take-up on the upper magazine and ran a belt around that, so that when you're running backwards it acts as a take-up. When running forward it acts as an over-running clutch and has no effect. Aside from that the only precaution we take is to lift up the sound pad roller when running backwards so that there's less tendency for the film to run off the sound drum. Also the projectionists usually back off on the pressure plate in the picture aperture. But aside from that we've experienced no trouble whatever, stopping and reversing as often as we please.

Mr. Zambuto (Comments submitted in correspondence subsequent to Convention discussion): In connection with the discussion on signal-to-noise ratio obtainable from a magnetic striping of half the width of a normal optical soundtrack, I wish to bring to your attention the following.

After striping, the available width of the optical soundtrack for scanning is: 50 mils for a normal 35mm track, and 36 mils for a 16mm track, assuming the scanning beam scans the whole width of the track. Edge irregularities of the striping have been stated to be of the order of one mil. This gives us a ratio of 100% modulation on the optical soundtrack to noise modulation from the edge of the striping of: 1/50 for 35mm track, and 1/36 for a 16mm track. It is quite evident that signal-to-noise ratio will be 34 db for the 35mm track and 31 db for a 16mm track. You will notice that in the above simplified calculations I have considered the density of the optical track (supposedly a variable-area one) to be the same as the optical density of the stripe and that modulation can affect the full width of the soundtrack. According to these considerations, these figures seem to me to be a little critical for good quality recording, even taking into account the fact that the edge of the stripe will be slightly out of focus in the scanning beam.

Mr. Lewin (submitted by mail): Mr. Zambuto's comments are probably valid as regards the effect of the irregular edge of the magnetic stripe upon the signal-to-noise ratio of the optical soundtrack. This is important when the optical track is used for re-recording or for showing purposes. It should be pointed out, however, that in the system described in my paper, the optical track is used for cuing purposes only, and therefore any noise present in it does not get into the finished product.

Preparation of Foreign-Language Versions of U.S. Army Films

By MAX G. KOSARIN

U.S. Army films, training, informational or documentary, have been prepared in foreign languages since 1942, at the Signal Corps Pictorial Center. Foreign versions of U.S. Army films are produced in various languages for use by our military missions in those countries where we are assisting in the training of national armies. Narration and lip synchronization are used, depending on whether the original film is of the narrative, off-screen type or dialogue, situation type. Superimposed subtitles are not used in foreign versions of military films because of the necessity of retaining, in translation, the entire content of the scenario or script.

At the outset of World War II, the United States had committed itself to arming countries of South and Central America. Under Lend Lease we shipped all types of war materiel and equipment to our neighbors to the South. We then had to train their armies in the use of our equipment and to train them as quickly as possible.

The U.S. Army Signal Corps Pictorial Center had already established its training-film production studios in Long Island City and it was therefore logical that these same films that were being produced to train our own Armed Forces, should be used to train our foreign allies in the use of the same equipment. Upon request from the Inter-American Defense Board, Washington, D.C., Spanish and Portuguese versions had to be prepared by the newly established department at the Center, the Foreign Adaptations Branch.

Since that time the program of producing foreign-language versions of U.S. Army films has grown to much greater proportions. In addition to servicing our military missions in South and Central America with Spanish and Portuguese language versions, films are now prepared in Korean, Turkish and German.

The original idea of cooperating in the training of Latin American armies has been extended to Europe and the Near East under the Mutual Defense Assistance Program; and, of course, to the Republic of Korea, practically from the first day of the invasion of South Korea in June 1950.

Training or informational films are of the narrative off-screen voice type, or the dialogue, situation type. The narration film presents no special or

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Presented on October 6, 1953, at the Society's Convention at New York by Max G. Kosarin, Chief, Foreign Adaptations Branch, Signal Corps Pictorial Center, 35-11 35 Ave., Long Island City 1, N.Y.
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military training problems. The text is translated and renarrated in the foreign language, just as any commercial or entertainment short or documentary film. In the military dialogue film, however, the entertainment-film practice of superimposing dialogue titles on American films for export to foreign countries, cannot be effectively used.

The conversation between the characters on the screen or the explanations being given to groups of soldiers, as part of the scenario in the film, actually carry the very teaching principles and doctrine being enunciated by the film subject. Superimposed dialogue titles at best can give only a small percentage of the actual dialogue. While this may be sufficient to impart the plot and general idea of the average entertainment film, it is inadequate in a training film, since it would be most ineffectual and even confusing to make a foreign-language version in which a small percentage of the message was being taught.

The technique of lip synchronization, therefore, is the only method in which the entire text can be translated and incorporated in a foreign-language version, outside of a complete reshooting of a film production in the foreign language, using foreign actors. The difference in costs is, of course, obvious.

In preparing for lip-synchronization recording, the dialogue must be translated in such a way as to retain the same number of syllables and to match the vowel sounds and the consonants. The inflexibility of the exact military language that must be used in the dialogue makes the task quite difficult. In entertainment films the dialogue can be altered to a great extent to accommodate the matching of lip movements. In a military film, a piece of equipment, the nomenclature of its component parts, the voice commands and similar phraseology, all must be exact in their application.

The translation of the original scripts requires native experts in each particular language who are familiar with the military and technical phraseology as well as the colloquialisms of the particular foreign army. Military advisers for technical language are sometimes requested by the Center. It is important to adapt the film's text so that no resentment is aroused in the foreign country, because of some sequence that might be misinterpreted or appear to be an extravagant claim or boast on the part of the U.S. Army.

Following the translation, the script is broken down into short sequences and the corresponding scenes are cut from the composite print and spliced into loops. The loop is projected in the recording studio, with the foreign voice actor reading his lines, while the recording director stands at his side watching the screen for cuing purposes, with the additional help of the original soundtrack running through earphones. The recording director cues the actor by a quick tap on the shoulder for each pause in the running dialogue, coaching the actor as to speed, projection of voice, delivery, etc.

There is another method for cuing in lip synchronization. This is known as the projected cue track and consists of an apparatus, synchronized to the projector containing the picture loop, which projects a special dialogue loop, containing the lines of the characters in the particular scene. The cuing is done automatically by the actor reading the words as they travel across the screen from right to left. The use of this method, however, entails considerable time at the editing machine, in preparing the dialogue loops. It is our feeling that this method, for all its costlier, time-consuming preparation, adds nothing to the preciseness of the synchronization, and as a matter of fact, results in a more mechanical, monotonous recording of the voice.

In lip synchronization, each sequence is recorded individually until all the loops or scenes have been completed.

Fig. 1. Reshooting sequences in foreign language, to be incorporated into existing Army films.

The recorded material, processed on optical film, is edited by lip-synchronization film editors who select the best takes, adjusting and inter-cutting them, with the result that a film is produced in which the original characters on the screen appear to be speaking in the foreign language.

The attempt at perfection in the technique of lip synchronization is made, not for the mere sake of technical or artistic achievement, but because the attention of the foreign student viewers would be distracted, if they were made conscious of the lip synchronization by a poorly executed technique.

In the adaptation of training films in foreign languages there are occasions when dubbing or lip synchronizing is not practical for reasons of subject matter, difficulty of technical language or colloquial expressions and situations awkward to translate. In such instances, scenes are reshot, matching as closely as possible the original backgrounds. Foreign actors are then used, substituting for the original characters. At other times lip synchronization is avoided by substituting scenes of characters on the screen explaining charts or equipment by full-screen foreign language inserts in which the voice is off-screen, or perhaps, just a hand or arm pointing to the subject matter is shown.

Army training films make extensive use of animated sketches to illustrate tactical situations, disposition of weapons and military units and also for the illustration of operating parts of equipment, electrical circuits and the like. In order to retain these valuable training sequences in the foreign-language version, without the expense, however, of remaking the footage originally in the foreign language, the technique of "duping" or masking is resorted to. This consists broadly of covering up the labels or texts of the original animation and substituting with foreign-language equivalents, reshooting the original background with the new foreign text, to produce a foreign version of the same animation. This is accomplished at a fraction of the cost of original animation.

Under the Mutual Defense Assistance Program, the U.S. Army, through its missions in Europe, has been assisting in the military training of their respective armies. As part of that training activity, we have been providing the preprint material from which those countries can make up their own language versions. In France, Belgium and Italy, lip-synchronized versions of the U.S. Army films are being prepared, while in such countries as Holland and Denmark off-screen narrated versions of U.S. Army films are being produced, even those that are dialogue type in the original. In Western Germany, where thousands of German nationals are employed by the U.S. Army in a variety of tasks, such as motor-vehicle driving and maintenance, warehousing, construction, etc., our own Army training films are used extensively, adapted into the German language at the Signal Corps Pictorial Center here in New York.

Soon after the outbreak of the Korean war in June 1950, the Center began its cooperation in overcoming the tremendous problem of training and training quickly the new Republic of Korea Army. Practically overnight we found ourselves making Korean language versions of U.S. Army films, selected by the proper higher authorities for their close relationship to the conflict at hand.

At first, we in the Foreign Adaptations Branch feared the lip synchronization of English language dialogue would be most difficult, translated into an Oriental language, such as Korean. Happily, however, Korean is a phonetic language and lip synchronization was thus facilitated.

The U.S. Army, from time to time, has received national and international documentary awards for certain Army-made films. We, who are engaged in the production of foreign adaptations, are particularly proud of a scroll, signed by the Chief of Staff of the Korean Army, commending the U.S. Army Signal Corps Pictorial Center for its "meritorious service and great contribution to the Army of the Republic of Korea and for the superior manner and high standard of technique employed in the film production of Korean military training films. These films have been of great importance to the instruction and training of Korean military personnel and have produced excellent results."

Language Conversion and Other Applications of a Special 16mm Magnetic Projector–Duplicator

By J. C. GREENFIELD

Techniques employed at the Naval Photographic Center, using a specially built, one-unit, 16mm photomagnetic projector and photomagnetic duplicator are described. Its use for recording (while projecting) on 16mm half-stripe composite prints, in foreign-language conversion, is reviewed. Sizable savings in time and material are realized.

As an integral part of the Inter-Hemispherical defense program the U.S. Navy has been engaged in the translation of training films for use by the navies of numerous Latin American countries as well as the Turkish Navy. In order to instruct the personnel of these navies in the use of the material and equipment received from the United States, we have actively cooperated with them by providing training films. In turn they have sent qualified officers here to do the translation work on the scripts and monitor the narrators in the foreign-language versions. One difficulty encountered during the past six years of this program has been that of shortening the foreign commentary sufficiently to match the picture, as originally narrated in English. For instance, there is no counterpart in Spanish for our word "counterclockwise." This made it necessary for the Spanish translators to improvise and say "the opposite way from which the hands of the clock rotate." Such difficulties are often met in matching the Spanish language with the picture.

Presented on October 6, 1953, at the Society's Convention at New York by J. C. Greenfield, U.S. Naval Photographic Center, Anacostia, D.C.
(This paper was received on April 19, 1954.)

Until recently, the recording and editing techniques employed by the Photographic Center and Navy contracting producers followed the more or less conventional pattern. The foreign-language narrator would, if it were practical, "narrate directly to picture," the picture being a 16mm or 35mm composite, running in interlock with a 16mm or 35mm photographic recorder.

In most cases it was necessary to resort to short takes and retakes, necessitating frequent stopping and rewinding of the composite projection print. This, of course, entailed considerable editing of the resulting foreign-narrative phototrack. Then followed the re-recording of the edited track while prepared music, and sound effects tracks as required, were mixed to produce the final sound negative for composite release. The above procedure is complex, costly and time consuming, especially since only six to thirty prints are required for each foreign-language subject, and only one to four prints in many other special motion-picture services performed at the Center, and since these are not budgeted for full production and release.

Using the magnetic medium, sizable savings in time and material are realized. Employing a professional combination photomagnetic-projector, photomagnetic-duplicator, several customary operations are by-passed. The direct result is a final mix, suitable for transfer to a release sound negative, or for duplicating magnetically striped prints.

Since this equipment will be fully described in the next paper in this issue of the *Journal*, only a brief functional description will be given here before discussing its use in language conversion and other applications.

The device (Fig. 1), which is all in one

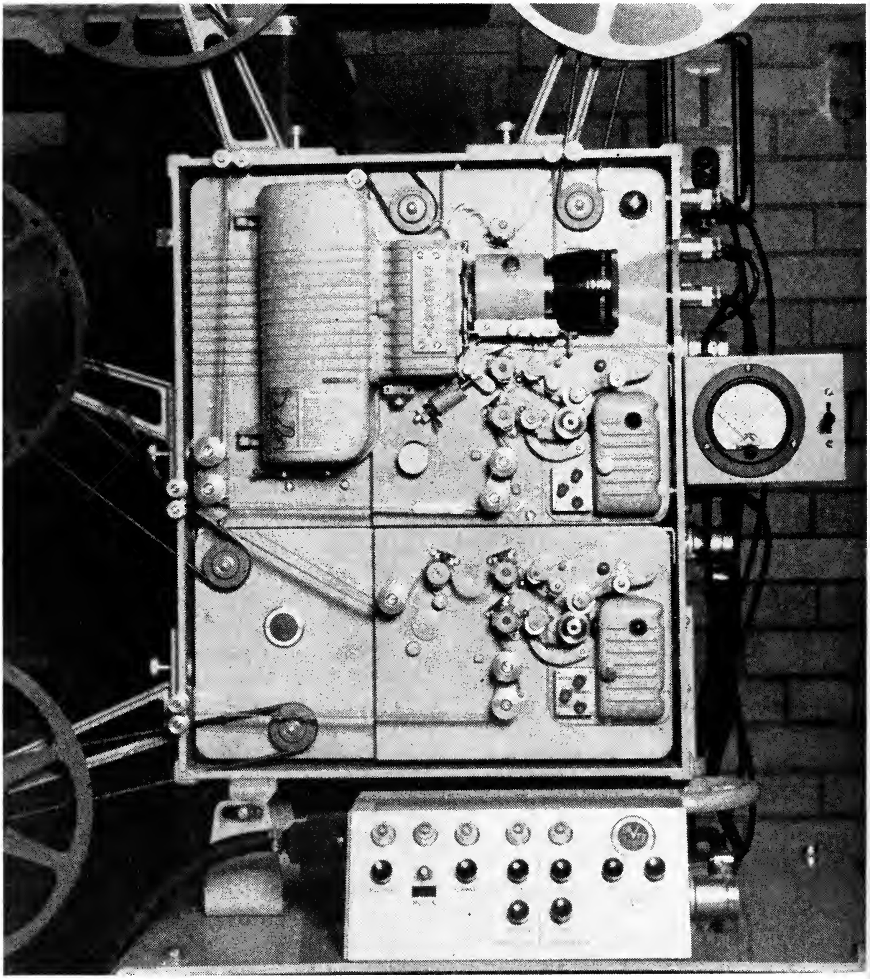


Fig. 1. Film-exchange transworder showing bias meter and pushbutton control unit.

unit, consists basically of a JAN projector, modified to include magnetic record-reproduce facilities, plus a duplication of the soundhead section of another JAN mechanism, similarly modified for magnetic record-reproduce. The two are commonly driven by a reversible synchronous motor. The magnetic reproduce preamplifiers are located behind the combination record-reproduce heads. A meter and spring-loaded switch have been added to indicate bias current on either head.

All other transmission equipment is installed in the rack-width base. Amplifiers and power supplies are of the plug-in type and inputs of all units are brought out to standard jack strips. A standard VU meter is used for level determination. A 10-w amplifier provides monitoring of any amplifier in the system by means of a selector switch. The simplified block diagram (Fig. 2) shows the four preamplifiers each with independent attenuator, the booster amplifier, master attenuator, V.I. amplifier, the two recording amplifiers, monitor amplifier, power supplies and bias-erase oscillators. The optical or phototrack reproducers are always energized and normal into preamplifiers 1 and 2. The magnetic heads when used as reproducers may be patched according to requirements.

A pushbutton control box with indicator lights (Fig. 1), which is remotely duplicated at the director's or narrator's position, starts, stops and reverses the film transport motor, turns the projection lamp on or off, and selects the magnetic record or reproduce function on the projector and duplicator heads independently, while running. The relay circuitry is so arranged that whenever the motor is stopped, the erase heads disconnect automatically and the record heads become playback.

This prototype multipurpose machine is in use at the present time in the narration-studio projection booth at the Photographic Center (Fig. 3). Wishing to use an existing projection port, and due to the location of a 35mm pedestal projector, it was decided to locate this equipment 90° to the normal projection beam, which projects through a small monitor room into the narration studio. A front-surface mirror diverts the beam and a removable ground-glass screen mounted on the monitor room window provides a bright, correct-reading picture, when viewed from the narrator's position. The remote-control box is located in the studio along with an additional monitor circuit for headphone use during recording. While adequate gain for microphone pickup is provided, the regular narration mixing equipment is used for speech pickup, and bridged into the new unit.

With this brief equipment description, we can return to language conversion, which was the first experience gained in the use of this flexible assembly. The nation concerned in the current conversion work is making increased use of 16mm projectors with magnetic sound reproduction, so that the end product is a 16mm composite print with magnetic half-stripe carrying the translation. Most of the Navy training films selected for conversion have only main and end title music, straight narration and little or no direct dialogue. The title music ends or fades before narration starts, and sound effects which have training significance such as Sonar "pings," etc., are usually "in the clear," or free of narration overlaps. Since with this machine the photographic half-track can be reproduced simultaneously while recording is taking place on the adjacent magnetic half-track, the phototrack music and effects can be re-recorded over to the magnetic track, along with the new narration, using regular mixing practices. The procedure proved very simple. Selected Navy 16mm release prints were magnetically half-striped. One print was threaded through the projector section, and another through the duplicator section of the machine,

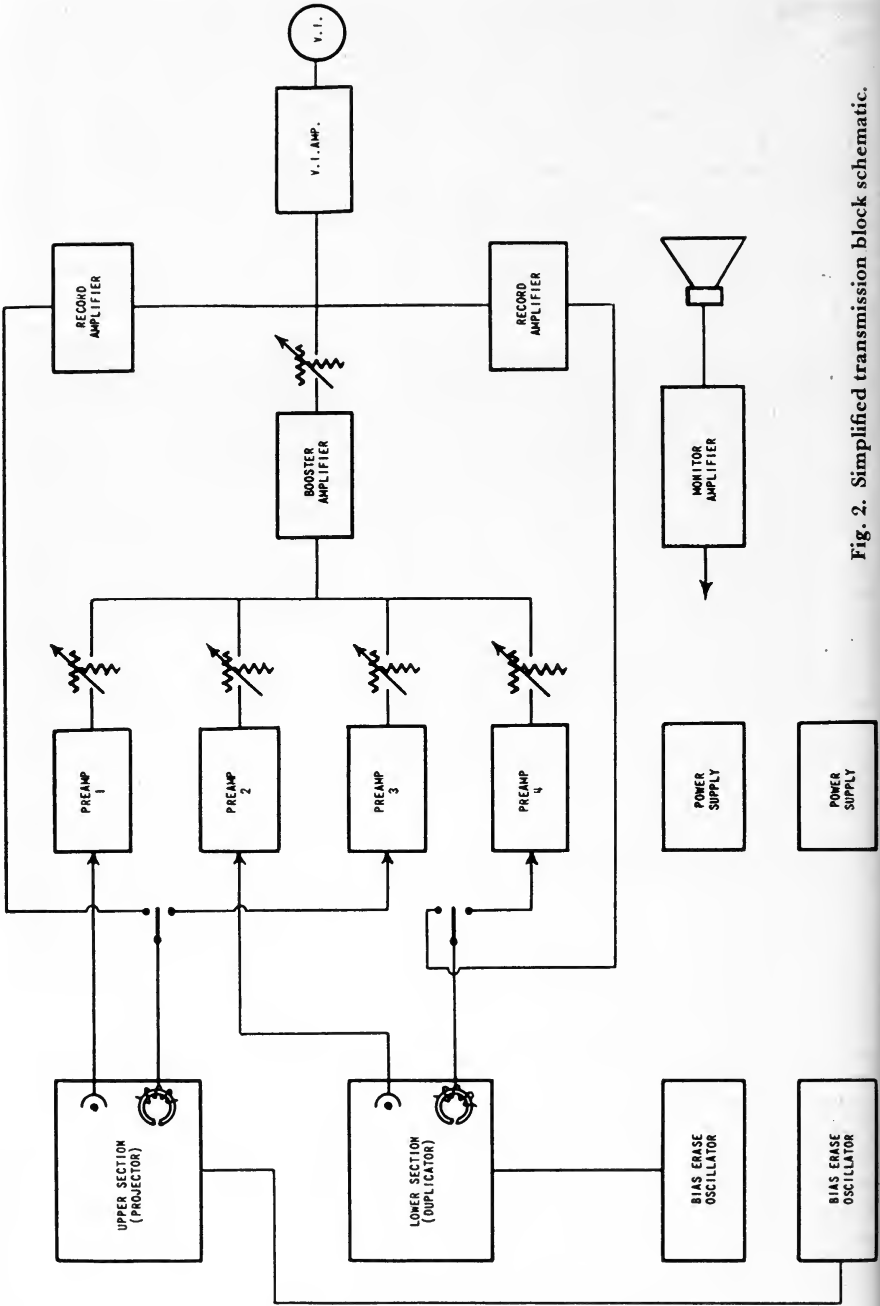


Fig. 2. Simplified transmission block schematic.

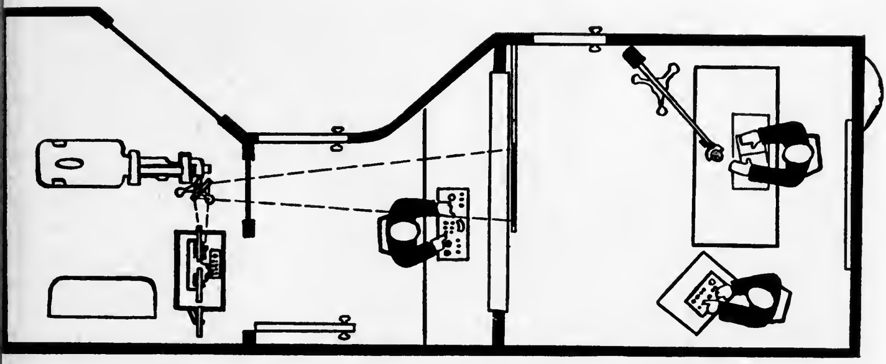


Fig. 3. Installation layout showing rear projection.

each with its sound-start frame at the sound drum. The narrator having previously rehearsed the translated script with a conventional projector, requires only a final rehearsal or two in the studio (Fig. 4).

Ready for an original take, a director or the narrator himself operates the remote control and the projector-recorder-duplicator starts. A regular sound technician controls the levels. Should the narrator make an error, the machine is remotely stopped (automatically switching the magnetic function to reproduce), reversed to a few scenes or sentences ahead of the error, and started forward again. Listening now to magnetic playback the record button is pressed promptly after completion of the last flawless sentence and the narrator continues recording. Corrections are made in this manner as required until the reel is completed. A final complete playback may reveal where an improvement might be made by changing or respeaking a sentence, phrase or a single word. This can be successfully done with careful timing and handling of the control buttons. This technique, together with the remote control system, is similar to that in use at the Signal Corps Pictorial Center for the past several years on 35mm magnetic recording equipment, described in a previous issue of the *Journal.**

The recording thus made will be virtually a final mix and release print at the same time, or as in this example the yield is two prints which will be used as masters for subsequent duplication by re-recording. Another method makes use of full-width magnetic 16mm film on the lower or duplicator head, and this becomes a dubbing master for additional prints.

Another technique in foreign-language work is suggested and is particularly effective when the original track carries a musical score and effects, and a complete rescoring job is not economically justified. The composite or mixed English track is re-recorded at full level until the foreign-langauge narrator is about to speak. The English track is then faded down but not out, and is returned to normal level whenever a pause occurs in the translator's narration. Thus the dramatic influence of the music and effects is preserved and the new language narration dominates the still intelligible English. It is well

*George Lewin, "Special techniques in magnetic recording for motion picture production," *Jour. SMPTE, 56:* 653–663, June 1951.

known that the meanings of spoken words or phrases can be modified by intonation, inflection and emphasis. In translation work, these meanings can be lost or are difficult to convert faithfully. This system allows the original language commentary to be compared with the translation, at any time.

Additional copies are made on the same machine. Half-striped prints are re-recorded on the lower or duplicator head from the completed magnetic half-stripe composite running on the upper mechanism. If a final mix was made on full-width magnetic film, it would be used as the duplication master.

In the future each country will receive a 50-mil striped print of the U.S. film, and, after listening to the English photographic track, will be able to have their own narrators record the foreign language on the 50-mil stripe. This will enable them to use their own dialects on their films. In the case of the various Spanish idioms, this was not possible before, since the translaters here were forced to use a "middle of the road Spanish" that would be only partially acceptable and understood by the Latin American Navies.

In another service performed by the Naval Photographic Center, the end product requested is a single 16mm composite print. The narration script is usually of the report or status type and the picture material furnished is frequently original color reversal. Previously this kind of service required the above-mentioned conventional system: record, print, edit, re-record, and print compositely. Real savings in time and material are made by simply magnetically striping the original 16mm color, if it is single perforation, and recording directly on it.

When 35mm equipment having comparable operational conveniences is generally available, great savings will be similarly realized. However, lacking such equipment at the moment, the 16mm projector-recorder-duplicator has been used as an interim medium. A typical case is one where a speed priority on a 35mm narration-to-picture job allows little time for track printing, cutting and re-recording. A 16mm one-light picture print is made from the 35mm work print. When this negative-reading print is projected, along with magnetic stock on the duplicator recording head, it provides the narrator with an adequate picture guide, and allows him to use the "correction-on-run" technique. Title music is mixed at the same time from $\frac{1}{4}$-in. tape, disk or film dummies. This complete 16mm take is now simply transferred by re-recording to 35mm photographic track for composite printing with the cut picture negative.

Another application of the machine involved its use as a playback and synchronizing device for the camera staging of a 5-min musical production number prescored on 35mm magnetic film. A 16mm magnetic copy of the music was made on the duplicator head and the machine so positioned that it could project onto the sound stage. A portable screen was set up out of camera range but visible to the clapstick slate man. A roll of opaque leader stock was threaded on the projector portion, on a start mark even with its counterpart on the magnetic roll. This was marked start number one. The director determined his several subsequent start points while underway, using the remote control to start, stop and reverse the magnetic record, which was reproduced through stage playback speakers. As each internal starting point was selected, five consecutive number punches were used to punch at 12 frame intervals 5, 4, 3, 2, 1 in the leader stock. Each of these internal starts was consecutively numbered. Several takes and camera angles were made from each start, and script notes made on which camera takes used which start number. The camera and machine were started a few feet ahead of the punched numbers,

Fig. 4. A Brazilian narration session.

now projected on the stage screen. The slate man would use the first four number flashes for rhythm, and clap for the camera on number five. Camera work completed, the punched synchronizing leader was now placed on a 16–35 synchronizer with a 35mm phototrack copy of the original recording, its start mark lining up with start number 1 of the 16mm leader.

The consecutively numbered internal starts were then transferred with grease pencil to the 35mm track print, the punched number 5 indicating in each case the closure of the stick on the camera coverage for that start. The 35mm track was then used as a work-print and cutting master.

Other schemes are possible and would probably work as well. For example, scratched bloops at similar intervals in the leader stock would provide audible beats for clapstick synchronizing, or blank magnetic stock could be used in the projection head and the stick itself recorded. However, this would limit the camera to one print-take per setup.

Some of the ideas set forth in this report serve simply to point up how almost daily in this still new field of magnetic recording, new uses, and application to older established procedures, are being tried, tested and used. It is axiomatic that any medium, technique or device that provides a more economic solution for the problems of language conversion and recording operations in general, while retaining the high standards set by the industry, is worth while.

Film-Exchange Foreign-Language Conversion Equipment

By E. W. D'ARCY

A new equipment has been designed to reduce the difficulty and expense of recording foreign-language translations on American films for export. Sound effects and music are printed on the film as a photographic half-width sound record and the other half of the sound record space striped for magnetic recording of the foreign language. The projector is designed to reproduce photographic and magnetic sound records on either soundhead or on both simultaneously. The magnetic recording head allows the foreign language to be recorded on the striping after the photographic recording is printed on the film.

EVERY NEW BASIC DEVELOPMENT of a component or system in our industry brings forth a variety of equipments designed to capitalize by application engineering on the potentialities presented. The recent addition of magnetic sound to motion-picture film is no exception to this axiom. The real economies possible in the conversion of sound motion-picture spoken narrative to other languages were justification for a new equipment design, using magnetic soundtrack. Such cost reduction can tremendously expand the world-wide use of film producers' products.

The economics of the situation are quite obvious. For example, if a film has a wide public interest, the cost of recording a foreign-language soundtrack by the photographic process could be justified. On the other hand, the bulk of films of all types produced in this country have a specialized interest, and the distribution of such films in foreign languages would not be economically feasible. Most educational and industrial films fall in this category.

Here let us consider briefly the present methods used in producing a foreign-language sound translation for an American film, with the typical case of a military film used for training purposes. Sound effects and a musical background are decided upon to enhance the interest of the subject matter. At this time a print of the picture only is produced. Using the picture as a master control with respect to scene length, a sound-effects soundtrack is produced. The same process is used in producing the music score. The narrative or dialogue portion of the picture is now recorded on a third track. These

Presented on October 6, 1953, at the Society's Convention at New York by E. W. D'Arcy, Consulting Engineer, 7045 N. Osceola Ave., Chicago 31 (formerly De Vry Corp.).
(This paper was received May 17, 1954.)

three soundtracks are reproduced synchronously with the picture. Each soundtrack is separately controlled, in a process called mixing, as to volume and tone quality, and is combined into the final end result of a soundtrack negative which is used to print the soundtrack on the final-release picture print.

In order to produce a foreign-language version in the manner described, it is essential that a new master-sound negative be produced for each language. This explains the mechanical cost factor in such prints, not including costs for talent, script translation, etc. A further complication is the difficulty of securing the best actors and actresses capable of doing a creditable job of converting the English language, normal for the picture, into the required foreign-language version, using the correct dialect. This almost insurmountable difficulty makes highly desirable an economical method of adding the foreign language in the using country.

It would appear that the answer to the problem would be found in a combination type of release print in which the sound effects and music score are combined and printed on the film as a photographic half-width soundtrack, the other portion of the normal soundtrack space being striped with a magnetic sensitive iron oxide on which the foreign narrative could be recorded in the using foreign country. Such a soundtrack could be reproduced either by means of projectors capable of reproducing the magnetic and photographic soundtracks simultaneously, or by combining the sound on the photographic track with the foreign narrative in a final mixing operation onto the magnetic half-track sound striping applied to the release print. Obviously, equipment capable of producing such a final end product could be used for producing other release prints by re-recording and would eliminate the need for all field projectors to reproduce photographic and magnetic soundtrack simultaneously.

In the addition of languages other than that used as the primary release language, where the release print is a composite incorporating the background music, sound effects and spoken narrative, a considerable improvement in rapid revoicing can be attained by reproducing the photographic sound normal for the film through a headset for the narrator's aid in cuing the revoicing of the film. This technique has been described in some detail by George Lewin elsewhere in this issue.

Film-Exchange Language-Conversion Equipment Needs

The preceding background establishes a situation calling for a specialized piece of equipment with the following facilities for use in film-exchange foreign-language film conversions.

(1) The entire equipment should be self-contained and transportable on rubber-tired truck casters. This is most convenient in a film-exchange type of operation.
(2) Picture-projection facilities should be incorporated in the equipment, allowing synchronous projection of the print with either or both the picture-projection and sound-film phonograph soundheads.
(3) Facilities should be incorporated for the reproduction of photographic and magnetic soundtrack on either or both sound reproducers simultaneously.
(4) The equipment should be capable of producing magnetic soundtrack of professional quality economically by re-recording.
(5) The equipment should be capable of making a professional language conversion with sound effects and music background.
(6) The electronic amplifier should incorporate adequate input-control facilities of conventional design to produce an acceptable magnetic sound record.

(7) Switching should be rapid enough to permit dialogue corrections and insertions of a phrase or less in narration without switching transients or thumps.

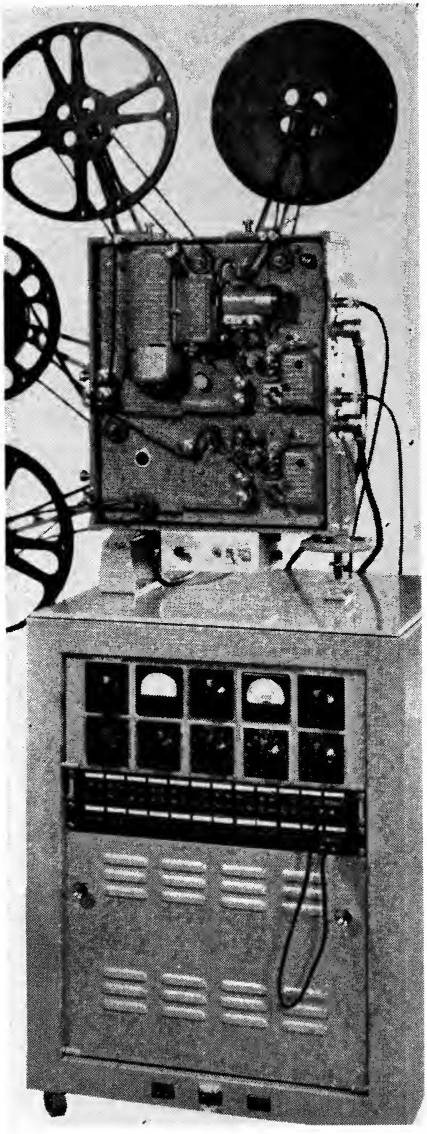


Fig. 1. Film exchange transworder.

(8) The equipment should be capable of remote control for forward and reverse operation.

(9) SMPTE standards should be adhered to completely with respect to both picture projection and sound-film reproduction.

General Description

A variety of equipment designs might be postulated from the preceding desirable performance objectives. A specific design answering to the preceding performance objectives is shown in Fig. 1. It will be noted that this equipment resembles the double systems used in the screening of 35mm rushes in review rooms. However, a basic d fference exists in that both the projector soundhead and the sound dummy are equipped for the reproduction of optical soundtrack and for simultaneously reproducing or recording sound on magnetic striping applied over one-half of the optical soundtrack.

Subassembly Construction

The basic projector element is identical to that supplied to the Armed Forces and identified as the AN-PFP-1 16mm projector set, with a separate 20-w output amplifier. The Armed Forces MIL-P-49B specification describes the

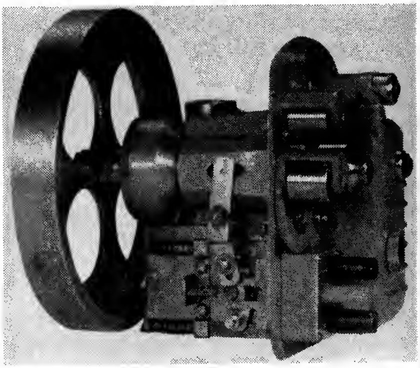


Fig. 2. Magnetic/photo soundhead.

performance characteristics of the projector very thoroughly.

The complete projector is an assembly of five major subassemblies, namely, the front mechanism film-drive plate, rear mechanism lamphouse and drive motor mounting plate, drive-motor assembly, exhaust-motor assembly, and the soundhead assembly.

The photographic soundhead assembly is shown in Fig. 2. Many variations of this soundhead have been developed to meet various needs since the basic equipment design was released.

The drive motor powering the mechanism also is a complete subassembly, which permits the use of a variety of drive motors, with the desired electrical characteristics. For example, a $\frac{1}{20}$-hp synchronous motor is used for powering the language converter. It is a complete unit, and removable by four screws.

Since this paper deals mainly with the sound portion of motion-picture equipment, a detailed description of the optical magnetic soundhead, the heart of the "Language Transworder," is most pertinent. As previously discussed, the basic design allows segregation of the soundhead as a subassembly. Figure 2 is a view featuring the selective switching and magnetic head film-contact pushbutton controls. A factor which influenced our soundhead design greatly was the Armed Forces requirements with reference to the mechanical strength of the equipment.

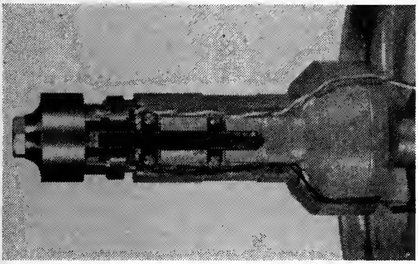


Fig. 3. Light pipe and magnetic head mounted in bearing housing.

Since the capacity of the projector mechanism to withstand shock must not be reduced by the addition of magnetic sound, the diameter of the shaft supporting the sound-filter drum and inertia wheel had to be retained in its full section. One of the service ruggedness tests involves dropping the mechanism several times from a height of 18 in. to a concrete floor. The shaft size was therefore determined on this basis, and not by its normal functioning strength requirements. Hence, the shaft diameter is 0.421 in., a very husky shaft for such a simple operation.

The preceding condition dictated a magnetic-head mount which would be located on the exterior of the sound drum-bearing housing and would not result in any reduction in section of either the sound-drum inertia-wheel shaft, or the bearing housing itself. The resulting magnetic-head mount design will be described in detail hereafter. An additional very important factor was the requirement that the equipment reproduce photographic sound, simultaneously with either magnetic sound recording or reproduction. Figure 3 shows the photographic sound light pipe location as related to the record-reproduce magnetic head and the magnetic erase head. These are located on either side of the light pipe, with about one film-frame spacing between them. This spacing is quite significant for the particular foreign-language film-conversion use under discussion. The magnetic heads in their mountings are secured to the sound-drum shaft-bearing housing, resulting in a single assembly wherein the magnetic heads and film location are related to a single basic locating point, and reducing mechanical tolerance buildups to a minimum.

The available mechanical space dictated the need for a very minute type of magnetic record-reproduce head and erase head. The magnetic head is $\frac{1}{4}$ in. in diameter and $\frac{5}{16}$ in. in length, and, in spite of its small size, has a

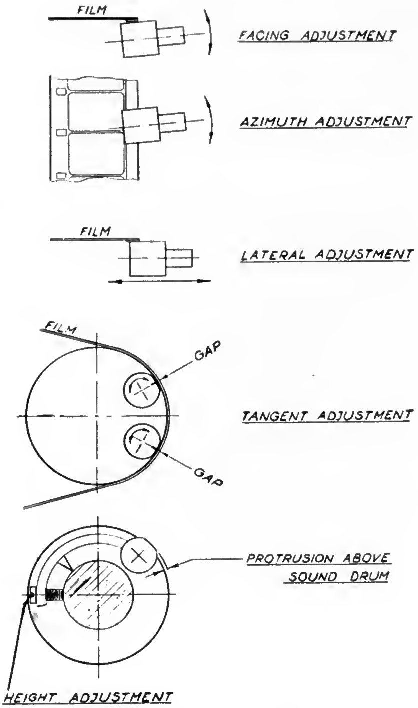


Fig. 4. Magnetic head adjustment requirements.

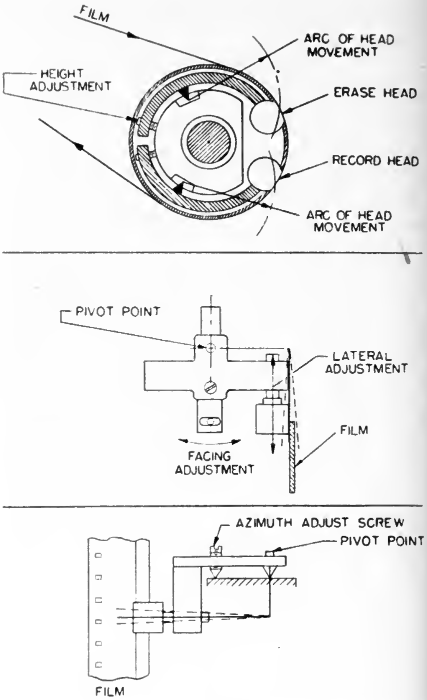


Fig. 5. Magnetic head adjustments.

permalloy shield incorporated for hum pickup reduction. The magnetic gap is less than 0.0004 in. for the record-reproduce head, and 0.010 in. for the erase head.

The method of holding the heads in contact with the magnetic coating on the film base has received a greater expenditure of engineering time than almost any other phase of the project. To understand why this was so, the points stressed on Fig. 4 should be noted.

The magnetic-head film-face adjustment is well illustrated at the top of the figure and is very simple to understand. The azimuth adjustment is also a very important one, otherwise film recorded on one machine will not reproduce well on another. The lateral adjustment allows the magnetic head to be positioned correctly for the scanning of half-stripe magnetic film. The tangent adjustment is essential when scanning magnetic track at the sound drum. If this adjustment is incorrectly made, the gap face will not contact the film at the correct tangent.

The magnetic head must be limited as to outward movement when not in contact with film. This is a basic need for splice protection. The head movement therefore is limited to about 0.002-in. or 0.003-in. protrusion beyond the film contact position at the maximum. Hence there is no difficulty in handling splices. Additionally, in order to reduce flutter and wows, it is essential that the magnetic heads be held against the film by a mounting of minimum mass and friction. Otherwise, bearing eccentricities would have to be held so close as to render general field use with low flutter impossible.

A solution to the above performance and mechanical design problems is shown diagrammatically as the top illustration in Fig. 5 which is the basic principle of our whole magnetic sound-head mounting system. The erase-head and the record-head locations can be seen from this figure. Normally the photographic sound light pipe lies between the two magnetic heads. Pivot points seemed the most desirable method of securing accurate mechanical head alignment with complete freedom from static friction, thus maintaining uniform head pressure on the film and minimizing the effect of bearing or drum eccentricities.

The requisite head-alignment adjustments are shown in the three parts of Fig. 5. Another very important head-mounting design objective was related to the accessibility of these basic adjustments for field alignment of the heads. This was achieved by making the head mount in a yoke, encompassing the bearing housing, as can be seen at the top of Fig. 5. Thus, the critical adjustments are 90° from the point of head contact, and are relatively in the clear. Figure 6 shows the heads and mounts as used in this equipment. Two are required, one being an erase head and the other the record-reproduce head. The total distance across the yoke is 1 in.

Press bars are located on the bearing housing 180° from where the head contacts the film and are operated by the action selector buttons which withdraw the magnetic heads from film contact when the heads are not in use. When optical sound only is used, both slide bars are pressed underneath the head yoke ends and withdraw both magnetic soundheads from contact with the film. If magnetic reproduction is desired, only one of the bars is withdrawn, thus engaging the record-reproduce head and disengaging the erase head, which is used only while recording.

Figure 7 is a bottom view of the sound-head showing details of the press-button selection device and the magnetic pre-amplifier which is incorporated within the soundhead. Post-equalization is introduced in the preamplifier by means of warping the feedback loop. A remotely controlled record-reproduce magnetic head relay is also incorporated in the same chassis.

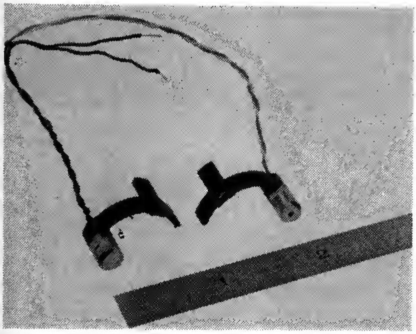


Fig. 6. Magnetic erase-record heads installed in mountings.

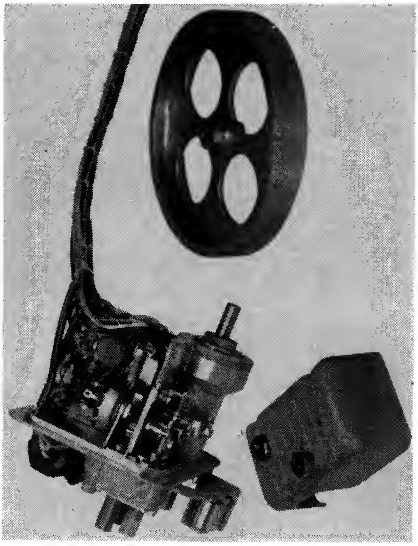


Fig. 7. Magnetic soundhead.

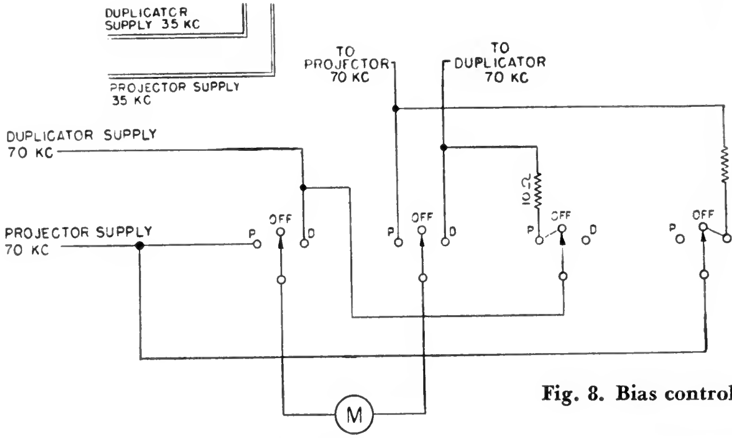


Fig. 8. Bias control circuit.

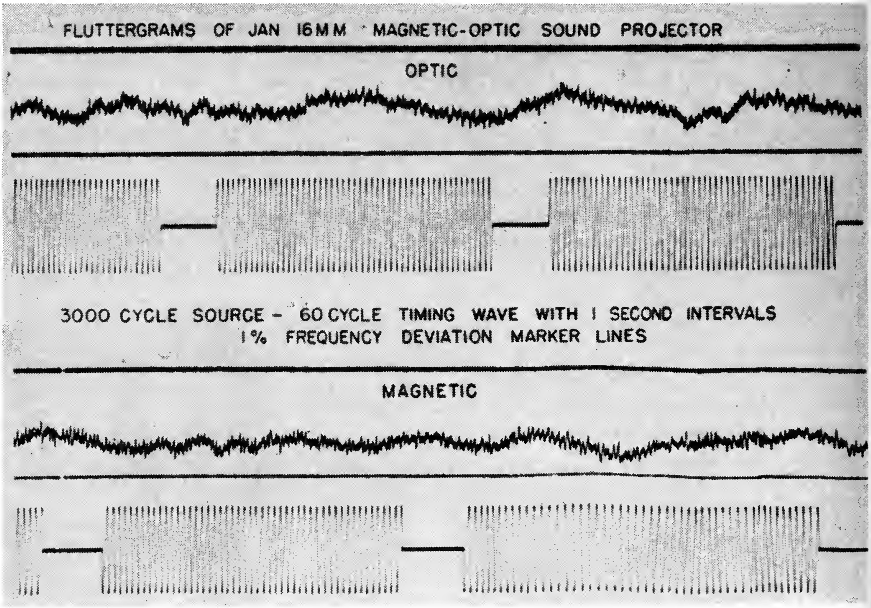


Fig. 9. Flutter graph.

The bias current is controlled through a bias-control box, attached externally to the transworder mechanism case (see Fig. 8).

The magnetic-head mounting attributes emerge as performance factors, particularly with respect to flutter. Figure 9 is self-explanatory. No additional speed variation has resulted from the addition of magnetic equipment. The basic electrical performance of the magnetic record-reproduce head is shown quite clearly in Fig. 10, made with constant current applied to the head. The magnetic reproduce end result using the present Society magnetic multi-

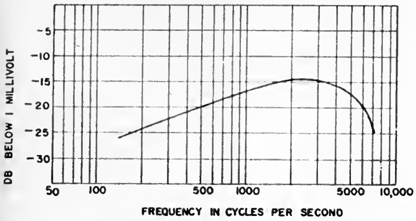


Fig. 10. Basic magnetic head record-reproduce characteristic.

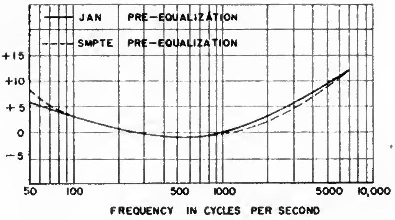


Fig. 13. Magnetic head pre-equalization required.

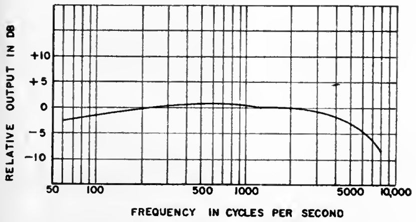


Fig. 11. Overall frequency response from SMPTE magnetic test film.

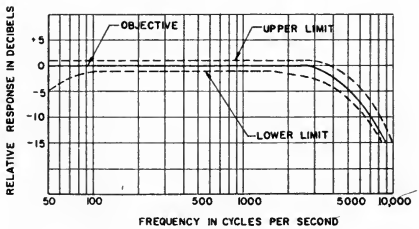


Fig. 14. Photographic sound frequency response using SMPTE test film.

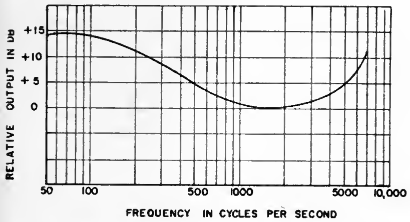


Fig. 12. Magnetic head post-equalization required.

frequency test film, is shown in Fig. 11. The post-equalization required to achieve this end result is shown in Fig. 12.

The pre-equalization required in order to duplicate the Society test film is shown in Fig. 13. This obviously varies from amplifier to amplifier and with respect to recording stock. This curve is made with Minnesota Mining and Manufacturing Co.'s 16mm recording stock and with our present amplifiers. It is quite close in characteristics to what was prescribed for the magnetic test films made by the Society.

Figure 14 is the photographic sound-reproduction curve of the system, made with the SMPTE multifrequency test film, and is as prescribed in the MIL-P-49B Armed Forces specifications as being the desirable curve. In fact, it is very close to many of the speaker-system curves that are in the Research Council recommendations.

Magnetic Erasure and Bias Considerations

There are some points about the erase, bias situation that are unique to the transworder equipment at this time. These are as follows (see Fig. 15): The small size of the erase head dictates a relatively high current input for effective magnetic flux density. Hysteresis losses were a problem. It was therefore necessary to reduce the erase frequency in order to secure adequate magnetic-field density without head overheating. However, the erase frequency resulting was too low for good bias frequency. This was solved

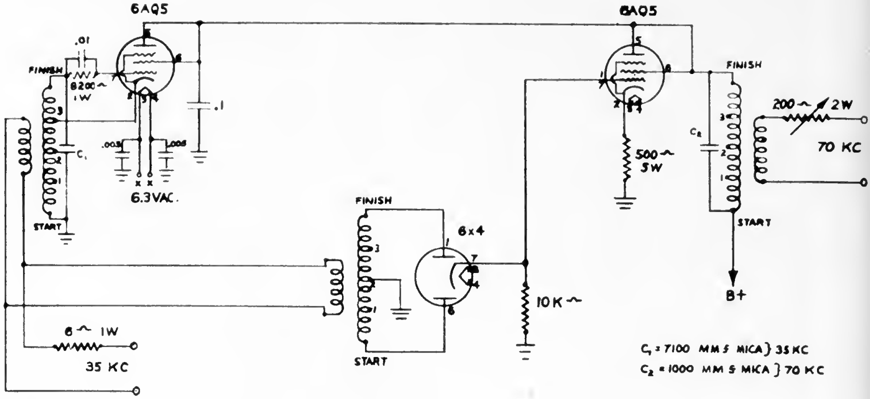
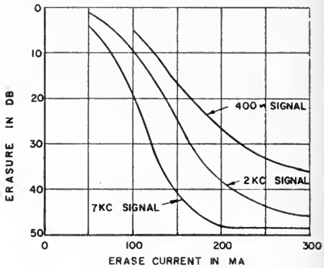


Fig. 15. Bias, erase, oscillator schematic.

Fig. 16. Erase effectiveness curves.



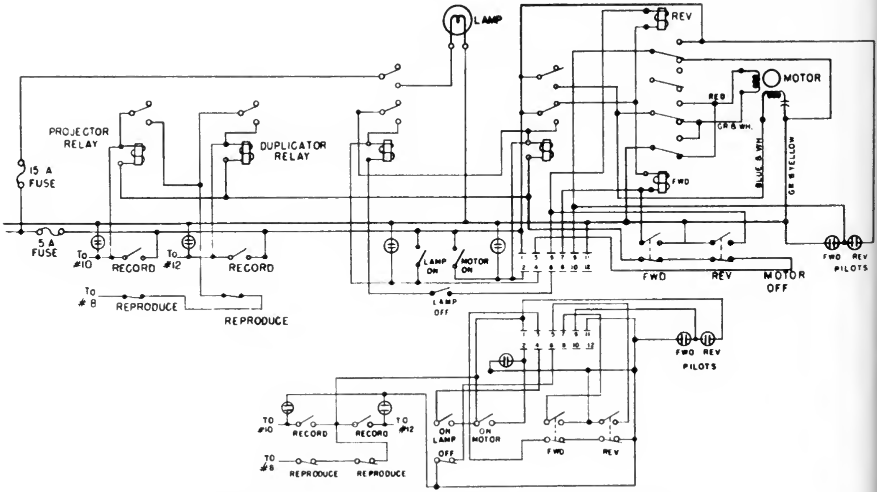


Fig. 17. Transworder remote control circuit.

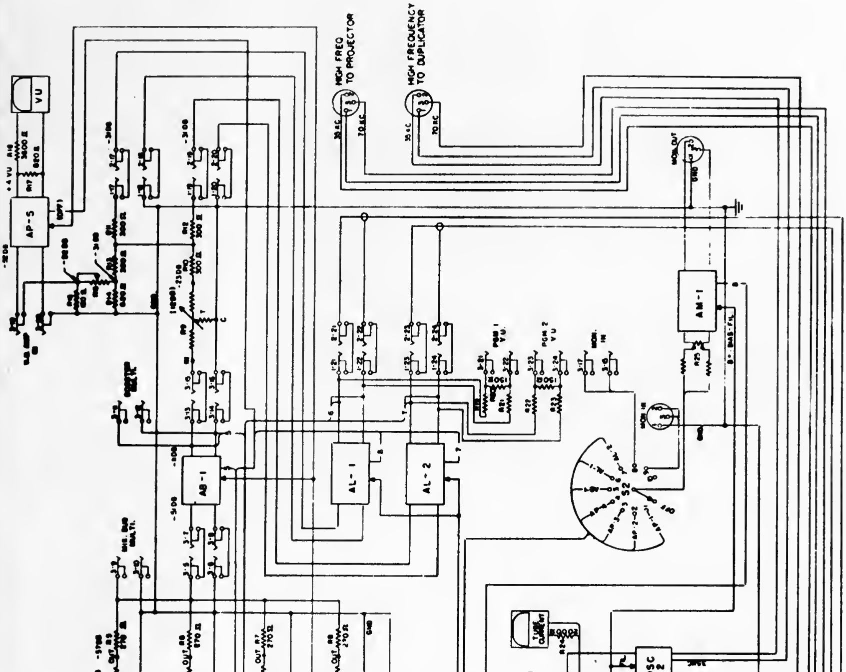


Fig. 18. Audio circuit block diagram.

in our case by frequency doubling the erase frequency for a bias frequency, otherwise heat frequencies developed in the audio channel.

The effectiveness of the erasure is shown in this family of graphs (Fig. 16). The erase head is identical in all respects to the record head with the exception of gap width which is 0.01 in. It is quite obvious that effective erasures should be related to various audio frequencies. The lower the frequency of the recorded signal, the harder it is to secure effective erasure.

Transworder Mechanism Details

Both the projector and sound dummy are shock-mounted to a common case, and are powered by a common $\frac{1}{20}$ hp reversible synchronous motor (see Fig. 1). Both take-ups and feed reels are driven through individual ball-and-ratchet type clutches. The soundhead duplicator is directly connected to the projector mechanism by chain.

Remote Control

All control circuits are completed through relays which are remotely controlled from a control box. Circuit action condition is indicated through parallel-connected indicator lamps. Projector duplicator control circuitry is shown in Fig. 17.

In normal use the narrator or language conversion director operates the equipment remotely. For rapid dialog corrections this feature is very important, and such corrections are very common in foreign-language film conversions.

Transworder Speech Input Equipment Mechanical Design

All the major speech-amplification and control-equipment components are mounted in the mechanism base cabinet (see Fig. 1). The required amplification is sectionalized to the maximum practical extent and all such units are plug connected and are removable from the front of the cabinet by lowering the front case cover. Service access to the interconnecting wiring is through a removable rear case cover. All required audio input controls are located in the top front case section (see Fig. 1).

The block diagram (Fig. 18) discloses in detail the amplification components and circuitry normal for the equipment. The patch panel affords access to all the amplification units and allows complete flexibility of use. All the amplification used is of a conventional design.

Discussion

Malcolm G. Townsley (Bell & Howell): This is not so much a question as a comment on Mr. D'Arcy's paper. Mr. D'Arcy referred, in some curves he showed, to an SMPTE Standard on Magnetic Test Film. I think it might be more accurate to say that that is a film that was prepared for circulation to collect data on the reproduce characteristics of various manufactured projectors. It is not yet a standard film and there is no implication that it is to reproduce in any particular way on any particular manufacturer's projector.

Mr. D'Arcy: I agree with Mr. Townsley. This equipment design, however, does reproduce the SMPTE 16mm magnetic test film flat.

Mr. Townsley: That's not to imply that it necessarily should reproduce flat in every equipment, because that hasn't been agreed to yet.

Mr. D'Arcy: No, I realize that is the case at this time. However, it is my hope that eventually all manufacturers will agree to a common reproduce condition. In my opinion this is essential for the progress of magnetic sound.

New 35mm Single-Film-System Kinescope Recording Camera

By ROBERT M. FRASER

A new 35mm camera for recording television sound and picture is described. Included among the features of the camera are a 51° pulldown, adjustable shutter and high-quality sound recording mechanism. A discussion of the technical considerations in the design of a kinescope recording camera is included.

The advent of transcontinental television networks, with problems of time-zone differences in program origination, created the need for new kinescope recording techniques to store for delayed broadcast both picture and sound. The requirement for high-quality picture reproduction dictated the use of 35mm film and the development of a new 35mm single-film-system camera. The techniques involved in kinescope recording for time-zone delay broadcasting have been described.[1] Briefly, this process requires the recording, processing, editing and playback on 35mm film of a kinescope recording within two and a half hours time. The quality of reproduction produced by the process approaches that of the original show. This process has been dubbed "hot kine" for understandable reasons.

Presented on October 7, 1953, at the Society's Convention at New York, by Robert M. Fraser, National Broadcasting Co., RCA Bldg., Radio City, New York 20.
(This paper was received on March 31, 1954.)

A second, increasingly important, use of high-quality 35mm kinescope recordings is in the storage of network programs as a means of protection to cover vacation periods or leaves of absence, for one reason or another, of talent. Also, it is possible to reduce costs by recording several programs, such as daytime serials, in one day for subsequent release during the following days. This releases the studio and crew for other assignments on other days, increasing the productivity of the unit. Savings in production costs can more than offset the higher costs of recording on 35mm film.

It is the purpose of this paper to describe the camera used for the making of high-quality 35mm single-system (sound and picture) kinescope recordings.

Technical Considerations in Kinescope Recording Camera Design

The photography of the kinescope or television cathode-ray tube presents problems in camera design not previously encountered in the motion-picture art.

The major difficulty is created by the need for transforming the 30-frames/sec television picture to a 24-frames/sec motion picture. Basically this requires the recording of 24 of the 30 frames of the television image. The other 6 frames are discarded. Let us review briefly those parts of the television broadcasting standards which play a part in the design requirements of a camera to be used in recording television images.

The standard scanning pattern consists of a total of 525 lines, divided into two interlaced groups of $262\frac{1}{2}$ lines each. Scanning proceeds uniformly from left to right along each of these lines. The scanning of the 525 lines takes place in $\frac{1}{30}$ sec; that is, 30 complete pictures or frames are transmitted each second. The scanning lines are laid down at a constant rate from the top to the bottom of the picture. The scanning pattern fills a rectangle four units wide and three units high. Each television picture or frame is divided into two vertical scanning periods of $\frac{1}{60}$ sec each. Each scan is known as a field. The horizontal scanning rate of 525 lines/frame or 15,750 cycles/sec is chosen so that in each vertical field scan the lines fall accurately into the spaces between the lines of the previous field. The field laying down the even-numbered lines is called the "lace" field, while the successive field is known as the "interlace" field, since it lays down the odd-numbered lines to complete the frame.

The image that is to be photographed is produced on the face of a kinescope, usually a tube with a P11 phosphor. While to the observer there is the illusion of a continuous picture because of the persistence of vision, the image is in reality highly discontinuous. Each picture element reaches its maximum brightness when excited by the electron beam in less than one millionth of a second. The light does not immediately disappear as the electron beam moves on, but decays according to an exponential law. The P11 phosphor decays to 1% of its maximum luminosity in approximately 0.001 sec. The photographic effect of the phosphor light radiation is measured by summing up the instantaneous light output through the entire exponential decay function.

A camera whose shutter is set accurately to $\frac{1}{30}$ sec will record one complete frame of the television picture. Regardless of what point in the scanning cycle its shutter opened, the shutter would remain open long enough to record the entire frame and would close at the same relative point in the scanning cycle of the subsequent frame. However, if the shutter is set so the exposure is somewhat less than $\frac{1}{30}$ sec, it can be seen that part of the scanning cycle will be missing. The result of this underexposure will be a low-density area or bar through the print where only the lines of one field have been recorded, the lines of the interlacing field having been blocked off by the too early closing of the shutter.

Conversely, if the shutter is open for a period greater than $\frac{1}{30}$ sec, more than one television frame will be photographed, producing an overexposure in that part of the picture where the kinescope beam had begun the scanning of the third field. This will produce a dark bar in the print. This bar, caused by over- or underexposure in kinescope recording, is popularly called "shutter bar," since in most cases its presence is due to an improperly sized shutter, although a shutter-bar effect may be created by other causes. If the film is not perfectly stationary during the entire exposure, interlacing of the lines in the recorded image will be destroyed. When movement of the film occurs, either just as the shutter opens or closes, an overlapping of the lines will create a shutter-bar effect. Destruction of interlace is apparent when the lines of one field fall on top of the lines of the previous field over part of or over the entire raster. This effect is sometimes apparent at that point in the scanning cycle where the shutter opens or closes, since it is then that the film may still be moving due to the shock of the rapid pulldown of the intermittent movement.

In monochrome television it is usual for the 60-cycle vertical scan rate to be locked to the local power supply frequency. Programs originating in other areas may have vertical scan rates that vary slightly from the local power frequency which is used to drive the synchronous camera motor. In these cases, a shutter-bar effect may be seen traveling through the recorded picture at a rate dependent on the frequency difference between the two localities.

The advent of color television has created another problem. In color television the vertical scan rate is controlled by the frequency of the color subcarrier, which in turn is selected to minimize interference problems caused by beats between the sound carrier and the color subcarrier. The resulting vertical scan rate is 59.94 cycles/sec. In order to minimize shutter bar in monochrome recordings of the color television image, it is necessary to use a means of driving the camera from the vertical synchronizing signal rather than the local power mains.

It is seen from the discussion above that in motion-picture cameras designed to record the television image at the standard 24-frames/sec sound speed the shutter should be sized accurately to be open for $\frac{1}{30}$ sec or 288°. The pulldown period is then dictated by the difference in time between $\frac{1}{30}$ sec and $\frac{1}{24}$ sec or $\frac{1}{120}$ sec. The closing angle of the shutter is 72°. Referring to Fig. 1, which diagrams the relative cycle of operation of the motion-picture camera relative to the television field and frame cycle, it will be observed that the points in the television scanning cycle where the shutter opens and closes are $2\frac{1}{2}$ fields apart in time. This means that any error in timing of the shutter, or shutter bar, will occur in the same position in the film on every second frame, so that this error

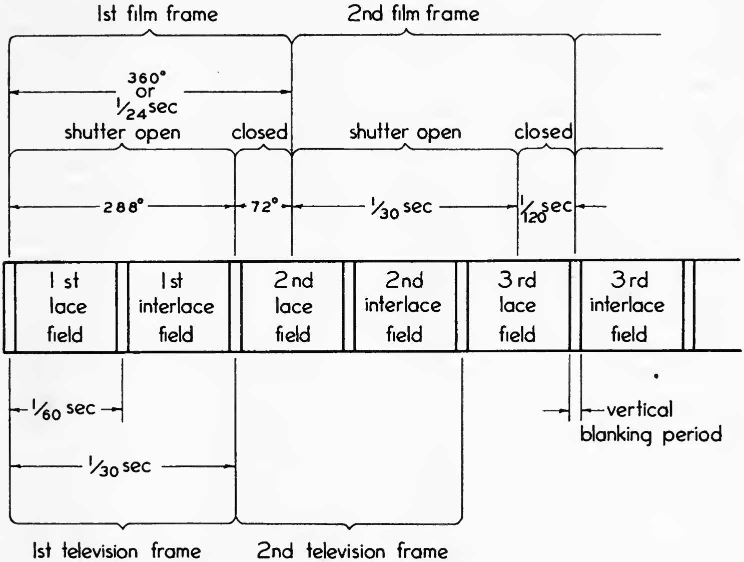


Fig. 1. Sequence of exposure and pulldown period timing of kinescope recording camera in relation to the field rate of the television image.

will show as a 12-cycle flicker when the recording is projected at normal speed. Even more apparent is the error introduced when the shutter has a flutter component that introduces varying exposure errors into each film frame. When this occurs the shutter bar may oscillate from black to white at some subharmonic frequency of 12 cycles, producing a very undesirable effect.

Still not fully understood is the part played by the failure of the reciprocity law in the creation of shutter bar. More specifically, it is believed that the residual shutter bar that remains after careful adjustment of all other variables, and which indeed varies from one emulsion batch to the next, requiring shutter readjustment, may be charged to that photographic effect known as the Clayden effect. The effect is described as follows: "If a photographic emulsion is given first a very short exposure to light of very high intensity and then a second exposure to light of moderate intensity, the two do not add in simple fashion. The high-intensity exposure effectively desensitizes the emulsion toward the second exposure."[2]

In photographing the kinescope, the exposure is the result of the integration of the total light output from the moment the electron beam strikes the phosphor until the light output decays to extinction. However, at the point in the scanning cycle where the shutter closes, only the highest intensity portion of the light gets through to the emulsion. But the same area of the phosphor was being scanned just before the shutter opened, so that the emulsion received the low-intensity portion of the light output first in those areas. The problem then is whether the density produced on the film for those areas where the entire light output was recorded continuously throughout the entire decay curve, is the same as for those points where the low-intensity "afterglow" was recorded first, with the high-intensity portion being photographed $\frac{1}{30}$ sec later.

The effect is most noticeable on a uniform-brightness field, with the exposure adjusted to produce a mean density of approximately 1.0. The density variation that can be attributed to the intermittency (Clayden) effect is small, but when the film is projected at 24 frames/sec the effect shows as a 12-cycle flicker, a point where the eye is most sensitive to slight brightness differences. As a result the shutter-opening angle will not be exactly 288° for best cancellation, but will vary a fraction of a degree from this value. Under the conditions of a uniform-brightness field on the kinescope, it will be found difficult to remove the shutter-bar effect completely, but a point can be reached where on average pictures the effect cannot be seen.

Features of the Camera

Severe demands are made upon a camera designed for kinescope recording. It is not at all unusual for the camera to be operated for two or three hours a day, a demand which places a severe strain on all components of the camera mechanism. A broadcast program cannot be delayed because of a failure of the recording camera. Therefore the utmost care must be taken to design the camera so that breakdowns will be at a minimum.

Most programs in television are timed to the half hour. While it would be desirable to provide recording continuously for one hour, the size of the film roll involved dictates a practical limit. In the Acme camera, the magazines are designed to load 3000 ft of 35mm film, which is sufficient for one-half hour of recording. Three-thousand-foot rolls of film stocks used in kinescope recording are supplied by the film manufacturers with one splice. The weight of the loaded film magazine is 52 lb, which makes plain the need for strong men as kinescope recording technicians.

Figure 2 is a view of the camera with the magazine mounted in place. The camera housing is cast aluminum, which

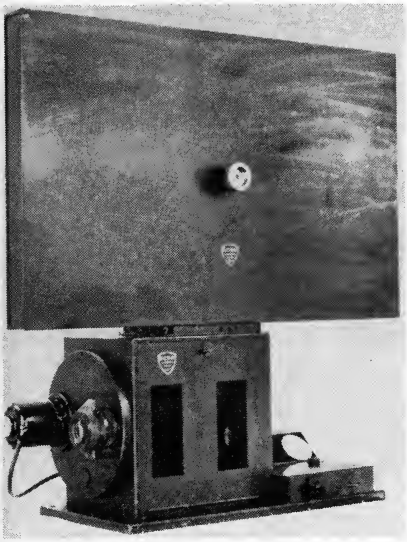


Fig. 2. The Acme 35mm sound-on-film kinescope recording camera. The sound optics, which are not shown, mount on the platform at the right.

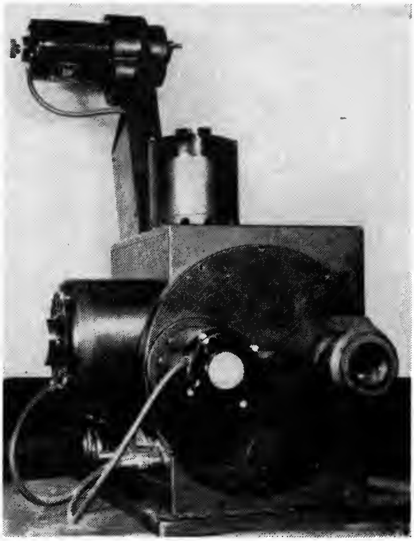


Fig. 3. The Acme camera showing the four motors. Access to the shutter-adjusting screw is through the covered port directly below the shutter shaft.

ensures rigidity in construction. Since the films normally used in kinescope recording are blue-sensitive only, it is possible to provide observation of the film path through red glasses inserted in the door, a valuable feature in assuring the technician that everything is "rosy." The panchromatic emulsion used in photographing the camera for Fig. 2 is able to "see" through the red glass.

A double-acting buckle switch is provided on each side of the main sprocket. This switch stops the camera if the film take-up should fail for any reason. A microswitch located on the rear wall of the film compartment, near the take-up side of the main drive sprocket, is actuated by the edge of the film. This switch will stop the camera if the film should break or run out. Another microswitch is located near the intermittent so that the camera will not run unless the film gate is properly seated.

All of the four motors used to drive the camera can be seen in Fig. 3. The use of three synchronous motors to drive the shutter, the intermittent action and take-up sprocket, and the sound mechanism, independently of each other, minimizes the interaction of the intermittent pulldown on the stability of both the sound mechanism and the shutter which, as discussed previously, must rotate with utmost constancy of motion to ensure shutter-bar-free recordings. The shutter motor, at the left, is a 110-v, $\frac{1}{75}$-hp synchronous capacitor start-and run unit, operating at 1800 rpm. It drives the shutter at 1440 rpm through a precision steel and fiber gear combination. Interlocking with the other synchronous motors is provided to maintain correct phasing of the shutter with the intermittent action during the starting and stopping periods. When the camera reaches operating speed, the mechanical interlock floats free so that the intermittent loading of the main drive motor does not reflect into the shutter action.

The main drive motor is mounted on

the back wall of the camera. It is a 110-v synchronous, split-phase, $\frac{1}{8}$-hp type running at 1800 rpm. It powers the intermittent action and the main drive sprocket. The motor is mounted so that its field may be rotated to obtain proper phasing between the pulldown and the shutter.

The sound mechanism is powered by its own motor mounted on the top of the camera with its shaft vertical. It is interlocked to the main drive motor during the starting and stopping periods, but runs independently at synchronous speed. This is necessary to maintain loop lengths in the camera. The independent action of the motor makes possible the high quality of sound motion and freedom from wow and flutter not normally associated with single-system sound and picture cameras.

The take-up is powered by a 110-v torque motor through a specially designed silicon clutch. It is capable of taking up 35mm film from a core diameter of 4 in. to a maximum diameter of about 18 in. at the end of a 3000-ft recording.

The design of the intermittent (Fig. 4) used in this camera is the outgrowth of two previous intermittent designs used over a period of a year and a half. While the earlier designs pull down the film in approximately 57°, this improved design pulls down in 51°, allowing ample time for registration of the film during the 72° closing angle of the shutter.

Two registration pins are used. The right or sound-track side pin is full fitting vertically and horizontally with dimensions of 0.078 by 0.110, while the left or outside pin is full fitting vertically only and is 0.010 in. from full fitting in the horizontal dimension. This allows for a slight horizontal dimensional change in the film. The pins supplied with the intermittent are positive pins. They may be interchanged with Bell & Howell pins to fit standard negative perforations.

It is disturbing to the designer of an intermittent movement for use in kinescope recording to find that the stability of film registration, which checks all right on the standard star test in direct photography, is poor when exposed to the kinescope raster. Slight movements of the film that are not noticed in ordinary photography, due to the integration of the exposure over the entire area during the entire exposure time, become very noticeable when exposed to the kinescope where the exposure time is measured in millionths of a second. The movement of the film during exposure causes a displacement of the television line structure which resembles somewhat the effect created by an under- or oversized shutter.

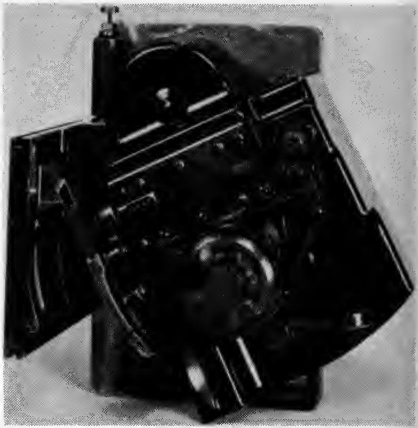


Fig. 4. The 51° pulldown intermittent.

In this design a full 288° period of solid film stability is provided. There is actually 304° of film registration, but between the 288° position and the 304° position the registration pins are in motion. It is necessary to phase the shutter opening accurately to coincide with the period during which the pins are stationary.

Figure 5 is an internal view of the camera, showing the threading path.

A modulated pressure pad is used to hold the film in the focal plane during exposure. Its pressure is relieved so that film is under a minimum of tension

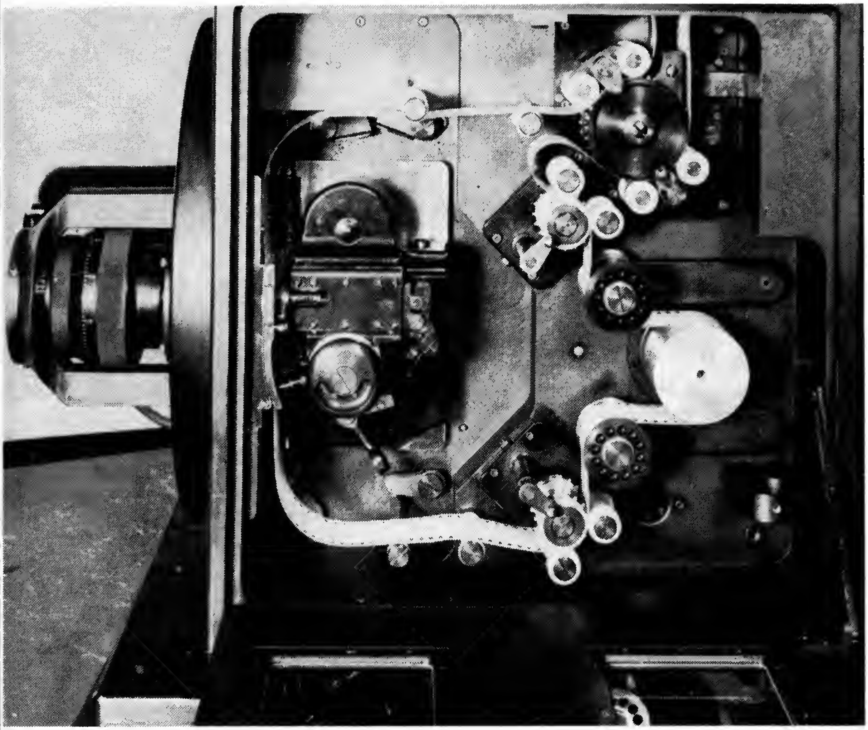


Fig. 5. The threading path of the Acme camera. The focusing lens mount is marked in increments of 0.0005 in.

during the pulldown period. All parts that come in contact with the film are of nylon or chrome-plated steel to reduce to a minimum the possibility of scratches.

For the accurate alignment of the camera with the image on the kinescope tube, a prism viewer is supplied. Its aperture corresponds exactly with that of the intermittent movement. It also is used for rough focus checks. Since the eye is relatively poor in resolution at the portion of the spectrum radiated by the tube phosphor, it is recommended that focus be set by exposing a test film at settings around the approximate point found by eye and selecting the optimum focus point by examining the film under a microscope.

In the early days of kinescope recording, it was customary to adjust the shutter angle by honing its edges with an Arkansas stone, or, in the case that too much had been removed, to paint the edge of the shutter with one or more coats of paint. This is necessary to adjust the exposure time to minimize shutter banding. In the new design, a calibrated screw-driver adjustment accessible through an opening in the front of the camera permits an easy change of the size of the shutter and allows a series of tests to be made readily to determine optimum shutter angle for minimum shutter banding.

The lens supplied with the camera is a 75mm Bausch & Lomb Baltar *f*/2.3 with coated lens. It is mounted in a micrometer focusing mount allowing adjustment of the lens focus in increments of 0.0005 in. The entire lens structure may be mounted to cover either a 5-in or 10-in. kinescope. A rigid supporting bracket holds the lens in place and aids in minimizing the effect of vibration.

The sound drive mechanism is driven through a separate electric motor which, as mentioned previously, is interlocked to the intermittent drive during starting and stopping periods. At synchronous running speed the interlocking mechanism disengages and the entire sound mechanism is independent of the varying loads of the intermittent drive. This motor provides a direct drive to a vertically mounted drive shaft having two worm gears which engage worms for the two sprockets of the tight-loop film system. Tension rollers are connected through a common coil spring, with damping provided by a dashpot filled with a viscous liquid. A heavy flywheel-and-drum assembly is mounted with precision bearings. Under normal operating conditions the wow content measured between 2 and 20 cycles is 0.04%, while the flutter measured between 20 and 300 cycles is 0.25%. It is believed that this can be improved by the use of closer tolerances in the gear drive.

The camera is designed specifically to accommodate an RCA MI-10387-A optical system (Fig. 6) which is capable of making either a negative or a direct positive track by a change in the position of the galvanometer. The only structural change from the standard studio optical system is in the position of the monitor screen which has been reversed to permit observation from the left side.

The optical-system base contains the necessary Cannon connectors, the lamp current rheostat, meter and switch; galvanometer on-off-bias switch and the galvanometer-to-line matching transformer.

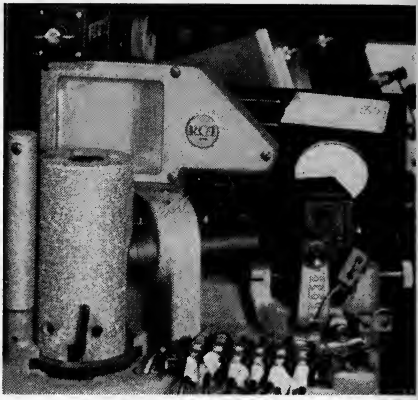


Fig. 6. The RCA MI-10387-A optical system.

Acknowledgments

The 35mm single-system cameras used at the NBC Kinescope Recording plants in Hollywood and New York are the result of joint design between the Producers Service Co., NBC, and RCA Film Recording. Specifications set by NBC for the camera included the sound-recording features.

The knowledge and experience of the RCA Film Recording engineers were utilized in arriving at the design of the sound mechanism of the camera. The integration of design information was made by the Producers Service Co. of Burbank, Calif., who designed and manufactured the entire camera, except for the optical system used for sound recording. This unit is a standard RCA item. The camera, while built primarily for NBC, is available to anyone from the Producers Service Co., except for the RCA optical system which is supplied by the RCA Film Recording Division.

The writer would like to express his appreciation to John P. Kiel of the Producers Service Co. for his aid in the preparation of this paper.

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Discussion

Wilbur G. Hill (Ansco): What size of core do you use and do you find it important to limit the minimum size of core? Also, what tensions do you get from the core end of the reel up to the full reel size? These questions are asked primarily because there has been some discussion at our meetings about core size and standardization of cores, particularly in light of the use of longer and longer film lengths.

Robert M. Fraser: The core size for the supply reel is a standard 2-in. plastic core as supplied by the film manufacturer. The take-up hub is $4\frac{1}{2}$ in. in diameter, so that from $4\frac{1}{2}$ to 18 in., the outside diameter of the 3000-ft film roll, we have a 4:1 ratio. As to the actual tensions, I'm not sure I can answer that. The silicon clutch, however, and torque motor seem to maintain a very steady pull on the film. We have no problems in starting and stopping a film at any point in the 3000-ft roll.

Mr. Hill: May I ask then, is the silicon clutch primarily to give you the lesser shock in starting?

Mr. Fraser: Yes, actually I didn't mention that. The switch for turning the camera on has two positions. In the first position, the take-up alone works and the motor grinds away with the film stationary. Then the switch is moved into the second position and the entire camera starts. There are a number of microswitches scattered throughout the camera to prevent the camera from operating unless there is film in it and every part of the mechanism correctly set in place.

Mr. Hill: Perhaps one more question would clarify a point. Do you find that the silicon clutch, in connection with your torque motor, eliminates possible cinching of the film when you're winding larger diameters? In certain applications, you'll find that if you use a torque motor or a constant pull on the film, you'll get a cinching at the core as the roll builds up to the larger diameters.

Mr. Fraser: Yes, that would be a possibility. We have seen nothing that we could attribute to that cause, however.

Multipurpose Optical Tracking and Recording Instrument

By SIDNEY M. LIPTON

A new tracking telescope type of optical recording instrument has been developed for missile programs at White Sands Proving Ground. The versatility of the instrument is discussed on the basis of different cameras and optical systems which may be used on the same basic mount. The possibility of its use as a cinetheodolite of moderate precision is also noted.

About three years ago, the Ballistic Research Laboratories at Aberdeen Proving Ground, Maryland, started the development and construction of a group of specialized optical instruments which were required for certain types of guided missile programs being conducted at White Sands Proving Ground, New Mexico.

The first four of these instruments were completed and tested in the summer of 1951 and were put in operation in the fall of that year. These instruments were designed to obtain photographic records with specified repetition rates, exposure time and magnification, and could be used for a variety of programs in which tracking and photographing missile flights were required. Similar instruments, which had been developed in the past, served as a basis for determining certain parameters such as exposure and filter factors, tracking rates, timing requirements and mount characteristics.

The availability of several additional gun mounts, which comprised the bulk of the instrument, and the varied requirements of different missile programs led to several studies which indicated the adaptability of the mount to hold optical systems and cameras other than as originally contemplated.

The instrument consists basically of a telescopic main optical system, a motion-picture camera, auxiliary guiding telescopes, a mount which moves the telescopes and camera in azimuth and elevation, and auxiliary electrical and electronic equipment.

The function of the mount is to move the main optical system and the camera, in both azimuth and elevation at varying rates in order to record photographically the flight of objects or missiles. It must be capable of 360° azimuth rotation and slightly more than 90° elevation

Presented on May 1, 1953, at the Society's Convention at Los Angeles by Sidney M. Lipton, Bendix Radio Corp., Baltimore, Md. (formerly of Ballistic Research Laboratories, Aberdeen Proving Ground, Md.). (This paper was first received Apr. 13, 1953, and in revised form Nov. 7, 1953.)

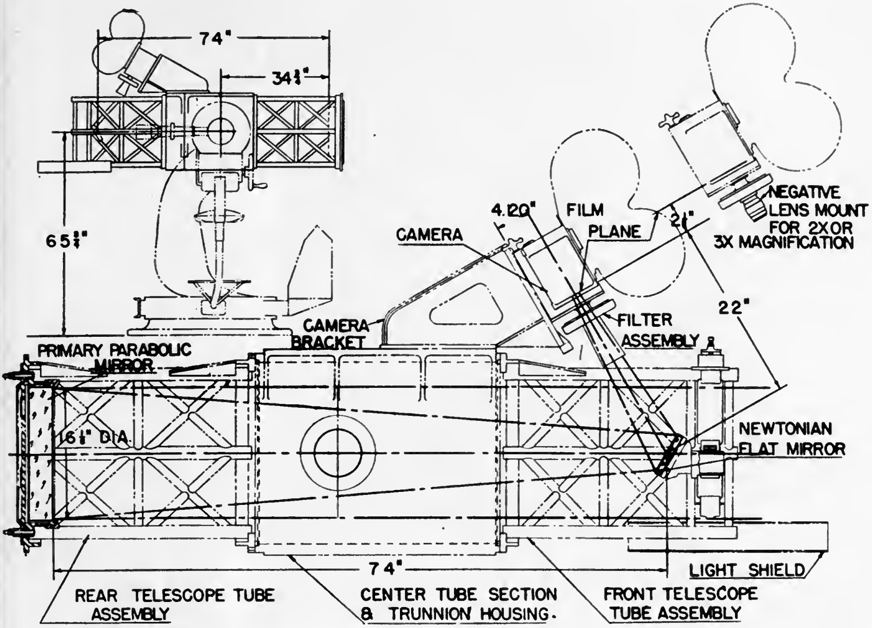

Fig. 1. Modified Newtonian System: effective focal ratio, *f*/6.33; focal length 96 in.

rotation. It must be large enough to accommodate the telescopic optical system, required by these problems, and rigid and smooth enough in its motion to minimize any vibrations or deflections which would affect the film record.

The obsolete Navy 5-in./25-mark, 19-gun mount, scheduled for salvaging at the time it was located, proved to be quite suitable after a certain amount of modification.

The existing elevating gear mechanism and associated bearings were completely replaced by a different design and relocated. The old azimuth bearings were replaced by new units of the same design and closer tolerances. The azimuth gear system was adjusted to minimize backlash. In the elevation system a patented dual lead worm and worm wheel designed by Gould and Eberhardt was used. The backlash in these instruments was 0.001 in. measured on the 17-in. pitch diameter of the worm wheel, which represents 0.12 mil or 24″ of arc.

The main telescope tube is composed of three sections: the center section consists of a cylindrical meehanite metal casting and the front and rear sections consist of either an open-tube framework or an enclosed cylindrical structure. The camera bracket, or supporting structure, is mounted on the center section.

Two short trunnion shafts, part of the center section, are mounted on a pair of precision angular-contact ball bearings (New Departure, A.B.E.C. No. 9 tolerance). The worm wheel is seen mounted on the left trunnion, as viewed from the main mirror to the secondary mirror of the telescope. The worm is caused to turn by a set of cluster spur gears, actuated by a handwheel. Two speeds are possible by axially positioning (pushing or pulling) the handwheel shaft; a slow speed of one turn of the handwheel

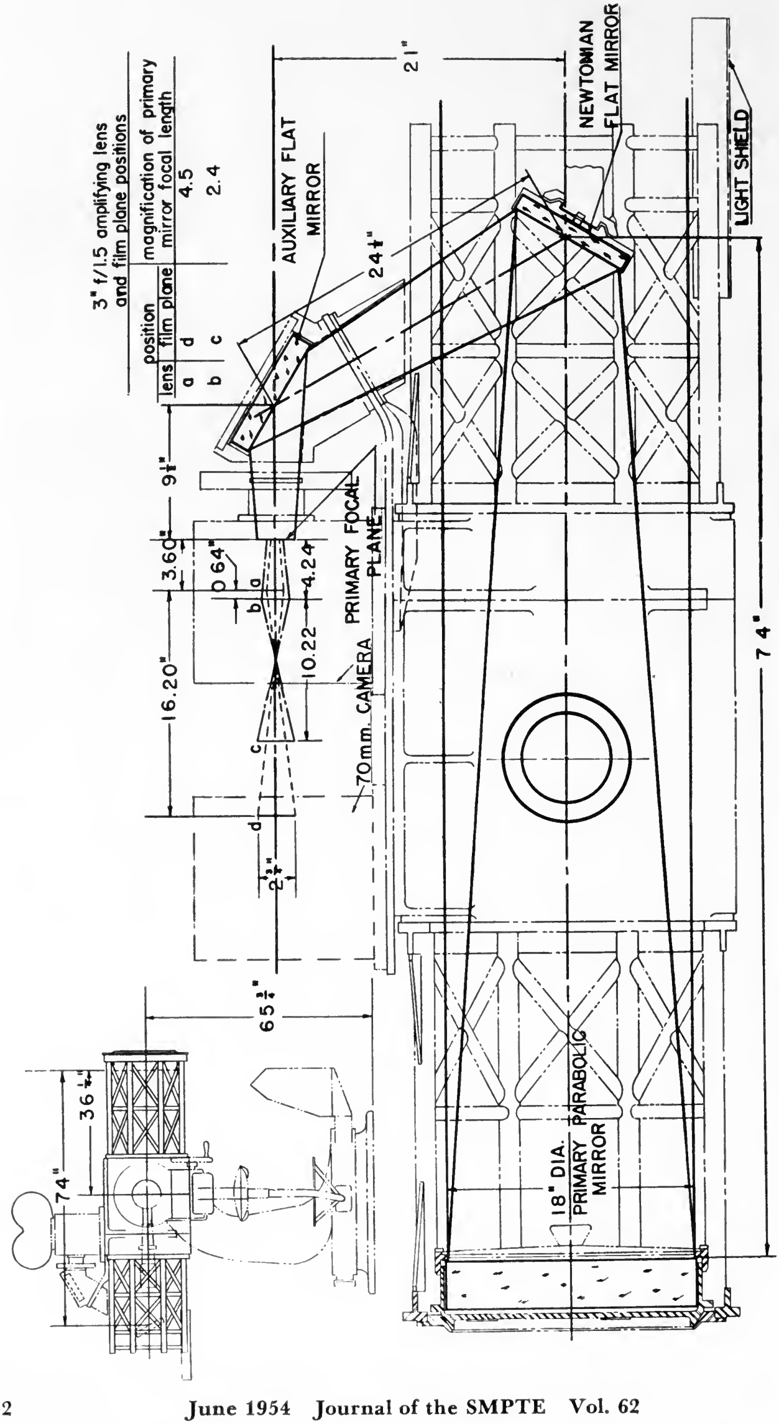

Fig. 2. Folded Newtonian system: effective focal ratio, $f/6.95$; focal length, 108 in.

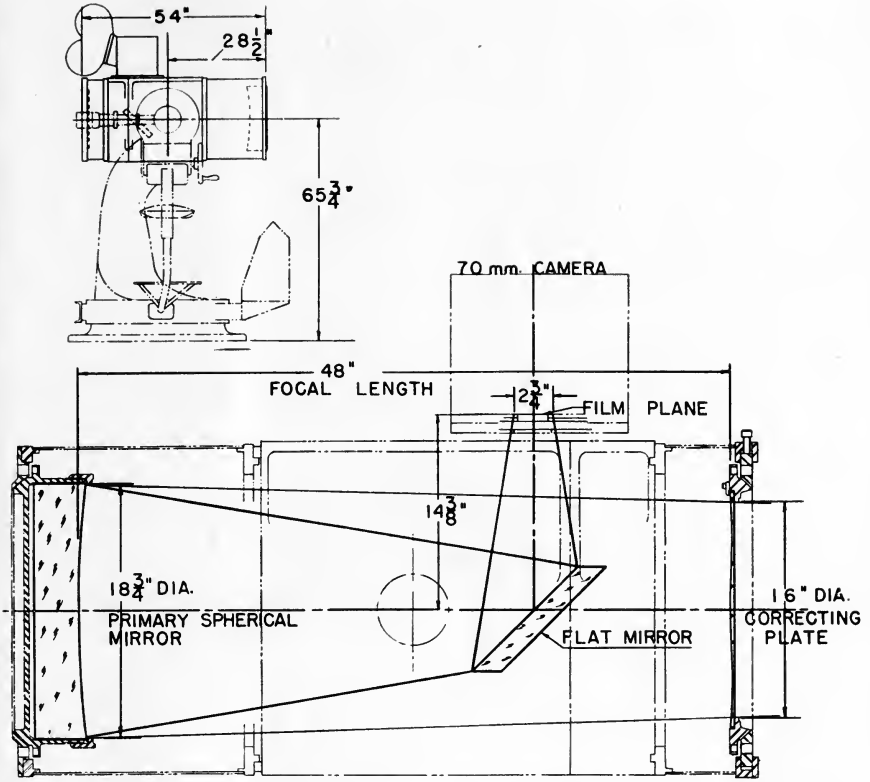

Fig. 3. Modified Schmidt (Wright) system: effective focal ratio, $f/3.75$; focal length, 48 in.

equivalent to $1\frac{13}{32}°$ elevation and a fast speed of four times this value, or $5\frac{5}{8}°$ per handwheel turn.

A mechanical elevation stop actuated from the worm shaft limits the elevation to a minimum depression of approximately $-3\frac{1}{2}°$ to a maximum elevation of approximately $92\frac{1}{2}°$. An external indicator arc is provided for coarse visual elevation-angle determination.

The pedestal, the main structural member of the instrument, rotates on two thrust ball bearings; a center bronze bushing serves to restrain lateral movement. The stand, or base of the instrument, holds the azimuth worm wheel, the bearings and an external indicator circle for coarse visual azimuth determination.

The pedestal rotates in azimuth by means of a worm which is turned by a pair of helical gears, universal joints, long shaft, sets of bevel and cluster spur gears and a handwheel. Two speeds are possible by axially positioning the handwheel shaft; a slow speed of one turn of the handwheel equivalent to approximately $1\frac{1}{2}°$ and a fast speed of four times this value, or approximately 6° per handwheel turn.

The usual angular tracking rates in the field are from 2° to 4°/sec. Occasionally as much as 8°/sec. has been successfully achieved. The two trackers

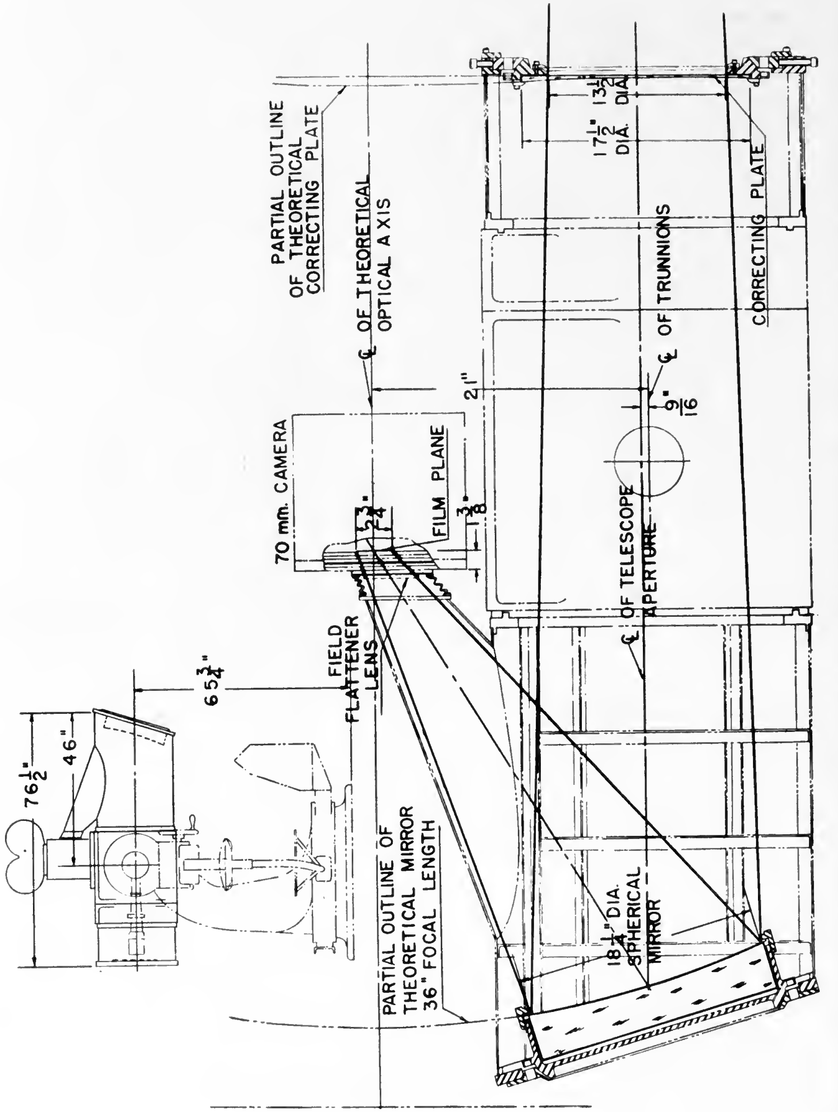

Fig. 4. Off-axis Schmidt system: effective focal ratio, $f/2.66$; focal length, 36 in.

are seated on opposite sides of the pedestal. The guiding telescopes used by the trackers are fastened so that the optical axis of the eyepiece is coincident with the centerline of the trunnions. These telescopes are 24-power, have a field of view of 3° and a $\frac{1}{8}$-in. exit pupil, and their reticles may be illuminated for night operation. An open gunsight with an illuminated reticle is mounted on the guiding telescope to provide for a large field of view.

The first main optical system used a modified Newtonian telescope, and the camera arrangement is shown in Fig. 1. The usual Newtonian telescope consists of a main parabolic mirror which collects the light from an object and brings it to a focus at the side of the telescope tube by means of a secondary flat mirror (the Newtonian flat) which is tilted to the main axis at an angle of 45°, thus diverting the main cone of light through an angle of 90°. In this modified Newtonian system the Newtonian flat is tilted to divert the main cone of light through an angle of 60° to a focus at the film plane of the camera at the top of the telescope tube. The front-surfaced parabolic mirror has a clear aperture of $16\frac{1}{8}$ in. and a focal length of 96 in. The front-surfaced Newtonian flat has a clear circular aperture of $5\frac{1}{4}$ in. Light shields extending from the camera and under the main tube prevent stray light from striking the film. The net focal ratio of this system is *f*/6.33. A filter wheel in front of the camera contains six different Wratten-type filters. An alternate camera arrangement is shown whereby the focal length may be amplified by a factor of two or three by the use of negative (Barlow) lenses of −4.8 in. and −1.8 in. focal length, respectively; two lenses were chosen so that quick changes of amplification could be made while the camera position was fixed. The use of such lenses was initially suggested by White Sands Proving Ground operating personnel. These lenses have been designed by Frankford Arsenal to give a resolution of at least 50 lines/mm over an image-field diameter of $1\frac{1}{16}$ in. with a minimum of aberrations.

When photographing at the prime focus, the position of the camera may be shifted along the optical axis, in advance, by means of a fine screw and dial indicator arrangement, in 0.001-in. increments. When using the negative amplifying lenses they may be translated along the optical axis initially or during the photographing interval by the same fine increments, to allow for changing object distances.

Using a standard 35mm Mitchell high-speed camera, the film aperture is 0.723 in. high by 0.920 in. wide. Of this, approximately a $\frac{3}{16}$-in. side has been reserved for the future presentation of instrumental position data. The resulting frame for recording the image field gives a diagonal of approximately 1 in. With the 96-in. focal-length system this is equivalent to a field of view of 36′ of arc or the frame is 26′ of arc square. At the edges of this field the tangential coma is approximately $5\frac{1}{2}''$ of arc. The film used for these instruments is Shellburst Panchromatic. The desired overall resolution of the system is 50 lines/mm over the entire image field.

Actual results on the range frequently show resolution of 2″ of arc on the film record.

Converting this to linear resolution on the film, for 96 in. focal length, gives approximately 42 lines/mm. It has been assumed that atmospheric "seeing" limits resolution usually to approximately 2″ of arc, and the above-mentioned results appear to confirm this, at least for daytime observations in the White Sands Area.

Figure 2 shows another type of optical system and camera arrangement which may be used with the same basic mount structure and central tube casting. Four instruments of this type are in the process of development and construction. This is a folded Newtonian telescope which is similar to the modified Newtonian telescope previously described, except that an additional flat mirror (the auxiliary flat) is used to deflect the main cone of light from its previously deflected path of 60° to the main axis to a path which is finally parallel to the main axis. The main parabolic mirror has a focal length of 108 in., the Newtonian flat has a clear elliptical aperture of 8.737 in. major diameter and 7.562 in. minor diameter deflecting the main cone of rays 60°, and the auxiliary flat has a clear elliptical aperture of 8.375 in. major diameter

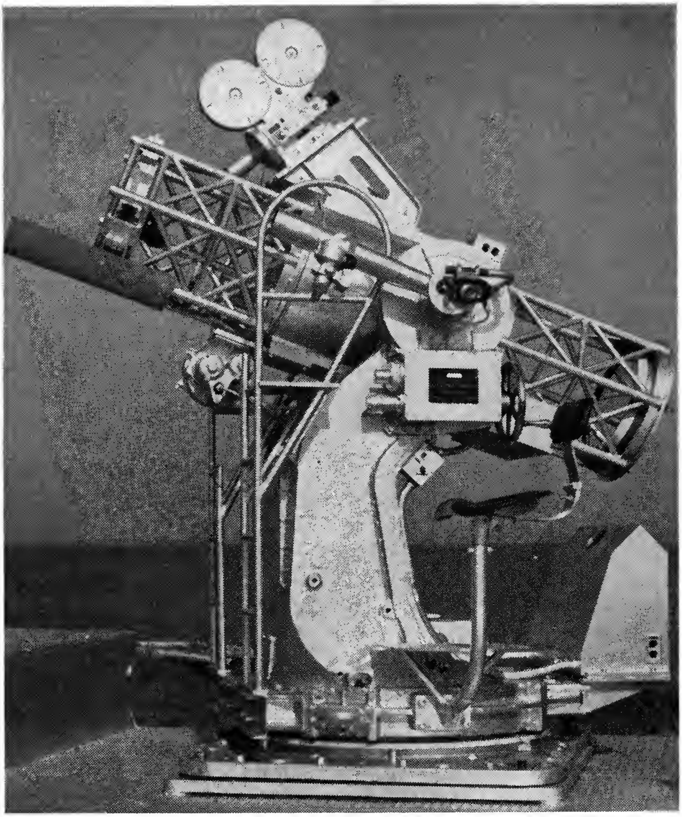

Fig. 5. Modified Newtonian system with Mitchell camera.

and 4.126 in. minor diameter deflecting the main cone of rays parallel to the main mirror axis. The net focal ratio is $f/6.95$. The film plane may be placed at the primary focal plane or it may be moved back as much as 20 in. for an equivalent focal length of approximately 480 in. Amplification of focal length is effected here by the use of a 3-in. focal-length positive lens.

Either a 70mm full-frame or a standard 35mm motion-picture camera may be used. When the 70mm camera is used at the prime focus, a thin coma corrector lens will be used.

Figures 3 and 4 show study layouts of two types of Schmidt optical systems which may be used with this mount.

In Fig. 3, the $f/3$ Wright-type modified Schmidt system provides for the use of either a 70mm or 35mm camera. The focal length is 48 in. with a net focal ratio of $f/3.75$. The camera is placed 90° from its usual position. It is assumed in this case that, as shown, the design of the camera will provide for a multiple-filter arrangement and an offset magazine which will not project beyond the front face of the camera. Focal-length amplification of 2 or 3 is possible by the use of negative lenses. Note that the overall tube length here is about 30 in. less than the one for the modified Newtonian.

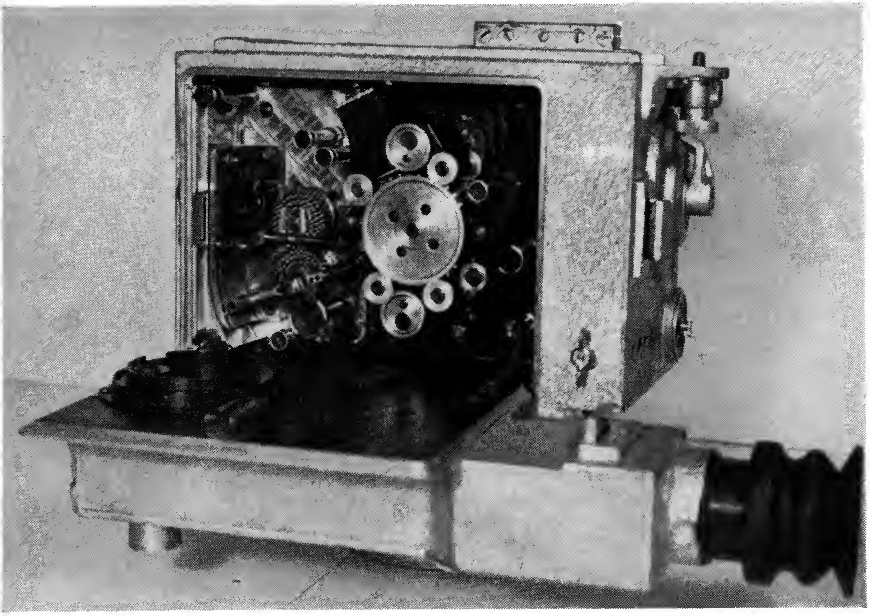

Fig. 6. Mitchell camera with timing housing installed.

Figure 4 shows an off-axis Schmidt system, similar to one originally proposed by Clyde Tombaugh of White Sands Proving Ground. The net light-gathering focal ratio is $f/2.66$, but the equivalent main-system focal ratio is $f/0.67$. Provided the correcting plate can be properly made, this system can give approximately $5\frac{1}{2}$ times as much light-gathering power as the modified Newtonian system described earlier.

These various optical systems, which may theoretically be used on the basic mount structure of this instrument, vary from a focal ratio of $f/2\frac{2}{3}$ to $f/31$. Actually, focal ratios of from $f/6.3$ to $f/19$ have been used in the modified Newtonian system.

Figure 5 shows the standard Mitchell 35mm high-speed camera with a 1000-ft magazine at the prime focus of the instrument. Its usual operation is at 60 frames/sec, using a variable-speed motor. Excellent results have been obtained with an exposure time of 1/2000 sec using either Wratten No. 15 or No. 25 filters.

It will be noted that here a standard 35mm Fastax camera is attached to the under side of the main tube. For certain types of programs, this camera operates at 1000 frames/sec using a 4-in. or 6-in. focal-length lens to record such events as light flashes. This camera is usually started automatically by a pulse signal generated by a central timing station. This Fastax camera has also been used experimentally at the prime focus of the main optical system giving very satisfactory results. The frame rate was 1300 frames/sec, using a Wratten No. 6 filter. The exposure time here was about 1/5000 sec.

Other camera arrangements are possible with the modified Newtonian system. A standard television camera may be mounted on the same camera bracket. This has been accomplished experimentally by using a camera which is part of RCA field camera equipment, TK-30A equipped with a 2P23 image-

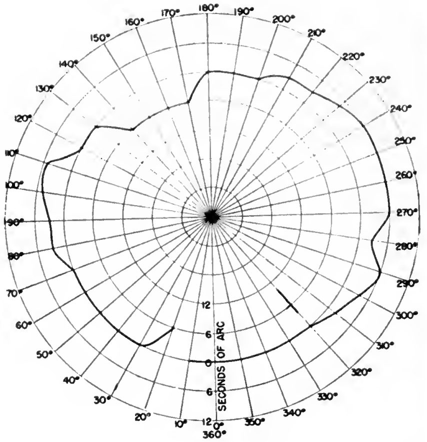

Fig. 7. Tilt of vertical axis of the multipurpose optical tracking and recording instrument.

Fig. 8. Film sample from modified Newtonian system.

orthicon tube. The image was viewed on a camera-control unit using a 5-in. kinescope tube. Only a short period of experimentation was possible at the time. Deep-red filters were used, such as Wratten Nos. 70 and 87, resulting in good images over horizontal lines of sight approximately 5 miles long. Only a few still-camera shots were taken of the image on the kinescope screen. The height from the base of this camera to the optical axis is 9 in. In order to accommodate this height, the sloping camera bracket was moved toward the main mirror.

In another experimental arrangement the Mitchell camera was mounted in its usual position together with a "pocket" oscilloscope. By the use of an auxiliary prism-and-lens assembly mounted on the camera door, the image of the scope signal was projected to a portion of the film which was receiving the telescope image of a plane in flight. By means of a photosensitive surface placed at the focal plane of the objective lens at one of the guiding telescopes, an electrical signal was generated which was proportional to the tracking error when the plane was not in the center of the field.

Figure 6 shows the arrangement of a timing housing in the Mitchell camera by means of which timing marks are placed on the film record to externally synchronize the record. Two parallel channels of timing information appear on the film, 100 pips/sec and coded elapsed time, both coming from the central timing station. In this arrangement, one of the existing sprocket guide units (the upper one) was modified to include a housing holding two GE Type NE51 neon bulbs. These lamps, before being pulsed, are kept ionized with a d-c voltage just short of the resulting glow fogging the film. The pulsing voltage is approximately 100 v.

The design and construction of the basic mount provide sufficient accuracy to enable the instrument to be used as a cinetheodolite of moderate precision.

It was noted previously that the elevation system, mounted in precision bearings and actuated by precision gears, showed a backlash of approximately 26″ of arc. Actual tests made showed that the maximum tilt of the horizontal axis during a rotation of 90° was 12″ of arc. The elevation worm gear was manufactured with an accuracy of less than 15″ runout in 180°. Some field tests made on the tooth error of the worm wheel of the elevation system show an error of approximately 10″ of arc.

The tilt of the vertical axis was measured and is shown on the graph in Fig. 7. It will be noted that the tilt is no more than ±6″ of arc. It is planned to install in the azimuth system of the folded Newtonian telescope the same type of precision gear system as now exists in elevation and to install also an improved type of bearing.

Data relative to the position of the instrument in azimuth and elevation will be placed on the film record by means of a coarse and fine precision selsyn system. They may also be recorded directly on magnetic tape or photographed with an auxiliary camera.

Figure 8 shows several typical frames obtained with the modified Newtonian system. The slant range to the plane was approximately 5 miles, the frame rate was 60/sec, the exposure time was 1/1440″ and a Wratten No. 15 filter was used.

Author's Note

Since the presentation of the paper in May 1953, motion-picture films were released to the public showing a Nike guided missile shooting down a plane. The film record was obtained by one of the instruments described herein, employing the modified Newtonian system, and originally designated as the IGOR (Intercept Ground-based Optical Recorder) Instrument.

75th Convention

A solid program of 58 scheduled papers was developed by Program Chairman Joe Aiken. This program was started during the Spring Convention in Chicago in 1952 when John Frayne was made Chairman of a special committee to give historical emphasis to the 75th Program. The twelve papers of a historical or tutorial type that resulted are now planned for publication in the *Journal* at the rate of one or two a month, after which they may be issued in a reprint volume.

The Roster of Papers Presented at the Convention will be published in a later issue of the *Journal.*

As forecast in detail in the March *Journal,* the program was enriched by the showing of many old-time films made available through cooperation of the Library of Congress, the Academy of Motion Picture Arts and Sciences and the Motion Picture Association. Jack McCullough was Chairman for these film arrangements.

During Convention week a special exhibit was open at the Smithsonian Institution which has one of the world's most important collections of historic photographic and motion-picture equipment including some by Edison, Armat, Mutograph, Levinson, Jenkins, Ruhmer and Lauste. The Library of Congress also had a special exhibit commemorating Edison's birth, showing much of Edison's earliest documents and motion-picture equipment.

Keith Lewis, Local Arrangements Chairman has reported: "Preparations for the convention were started in November. Committees were formed in January and the chairmen began working out all plans well in advance of the meeting dates. I think they did an outstanding job and to all members of the committees, we should extend the appreciation of the Society for what I think was a smoothly run convention."

The Convention registrants were kept posted by a well laid out series of signs supplied by Byron Roudabush who also, as Hospitality Chairman, gave Society members welcome help for their Washington visit.

Besides Jack Servies, Convention Vice-President, and other Society officers, those responsible were:

Program, Joseph E. Aiken
Papers, W. H. Rivers, S. W. Athey, G. G. Graham, C. E. Heppberger and R. E. Lovell
High-Speed Photography, J. H. Waddell
Local Arrangements, Keith B. Lewis, Byron Roudabush
Registration and Information, Howland Pike, Theodore Braun, Edouard Conte, Philip M. Cowett, Fred W. Gerretson, James A. Moses, William Nagel
Hotel Reservations and Transportation, Henry M. Fisher, John V. Waller
Hospitality, Byron Roudabush
Public Address and Recording, Jack C. Greenfield, Garth Burleyson, Stuart Cadan, Richard Patton
Projection, 35mm and 16mm, William Hecht, Wilson E. Gill, Ralph Grimes, Carl Markwith, Alfred S. Mueller, Tom Reed and William Youngs
Motion Pictures, Jack McCullough
Membership, Ray Gallo and Bill Reddick
Publicity, Leonard Bidwell
Ladies Program, Mrs. Jack C. Greenfield and Mrs. Keith B. Lewis

The convention accounts were audited at Washington by C. E. "Bud" McGowan of Stanley-Warner Theatres.

Attendance at technical sessions averaged 110 throughout the week. For the 16mm projection session on Wednesday afternoon and the laboratory-technical session on Thursday morning attendance averaged 150.

Total registration, weekly and daily, for the technical sessions totaled 549 compared with 860 at the previous Washington Convention. Compared with a Ladies Registration of 240 last time in Washington there were 105 registrants this time, though we are advised that a considerably higher number attended the reception at the White House on the basis of the pre-registration reservations.

On Monday noon about 200 gathered for luncheon and to enjoy an introduction to the Washington Convention by SMPTE President Barnett.

The principal luncheon speaker was Wally Watts of RCA who skillfully reviewed recent developments and their general potentialities for the industries, foreshadowing the impacts and applications to be described in subsequent technical papers.

On Tuesday evening 157 attended the Pioneers' Dinner at the Columbia Country Club to honor 26 members who were members of the Society in 1924 or earlier. A complete report of these pioneer awards will appear in a later *Journal.*

Instead of the usual Banquet and Dance, a Dinner-Dance was the feature entertainment, held on Thursday evening and attended by 203.

Besides the reception by Mrs. Eisenhower, the Ladies Program included a sightseeing trip to Broadcast House and National Cathedral, an evening at the Academia of the Motion Picture Association, and a trip to Arlington, Va., and Mount Vernon.

Complimentary theater admissions were extended by RKO Keith, Stanley-Warner Metropolitan, Du Mont (Lopert), Loew's Capitol, Loew's Palace, Playhouse (Lopert) and Warner Theatre (Cinerama).

Engineering Activities

Eleven technical committees, listed below, held meetings in Washington, during the 75th Convention, May 3–7, 1954. The minutes of these meetings are now being prepared for Committee circulation and copies will be made available to other interested parties upon written request. The highlights of these meetings will be reported in the next issue of the *Journal.*

Color
Film Dimensions
Film-Projection Practice
High-Speed Photography
Laboratory Practice
Screen Brightness
16 & 8mm
Sound
Magnetic Recording Subcommittee
Television
Television Studio Lighting

As reported in the April 1954 *Journal*, the Engineering Committee Manual, describing committee procedures, processing of American Standards and the overall engineering operations, is now off the press. Copies have been distributed to all the technical committees and are also available upon request.—*Henry Kogel*, Staff Engineer.

Board of Governors Meeting

At the May 2 meeting, the Board thoroughly reviewed current policies and plans, especially in relation to these critical financial times for the Society. After discussion about the costs for services which the Society renders, decisions taken at the January Board Meeting (see details in the April *Journal*) were reaffirmed by a heavy majority. This bore particularly on the matter of advertising in the *Journal*, plans for which are to continue as announced in the April issue. Aside from offering advertising, the Board considered such revenue-raising measures as increasing membership fees.

Convention plans firmly adopted include the 76th to be at the Los Angeles Ambassador Hotel, October 18–22, 1954, the program to feature color and to include a motion-picture and television equipment exhibit; the 77th at the Hotel Drake in Chicago, April 18–22, 1955; and the 78th at the Lake Placid Club, October 3–7, 1955.

Revision of the Society's Administrative Practices, under consideration for some time, was reported due for completion this year.

New Address

Late this month the Society's headquarters will be moved to 55 West 42nd St., New York 36, N.Y. The telephone number will not be changed. The American Radiator and Standard Plumbing Co., owner of the 40 West 40th St. building, is converting it to sole use by its own staff. The Society has been able to relocate at a more economical rental with substantially the same amount of space and in the same neighborhood which is convenient for travel, business and library facilities.

The New Journal

Beginning with the July issue the *Journal* will have a new format with the trim size increased to $8\frac{1}{4} \times 11\frac{1}{4}$ in. and the number of columns three to the page. The column widths and the basic typeface will be the same as in this issue. Binding will be by saddle wiring, the simplest way of binding, which will be particularly welcomed in view of difficulties with the May issue which was delayed a full week in binding after it was printed on schedule.

Advertising will be published in the new *Journal*. The New Members column will be resumed in July. Otherwise the substance and the policies of the *Journal* remain unchanged.—*V.A.*

Obituary

Fred Waller died on May 18 at his home at Huntington, L. I., at the age of 68.

He left Polytechnic School in Brooklyn at the age of 14 and went to work in his father's photographic studio. He entered the motion-picture field in 1905 as a lobby display creator. In 1918 he was operating a photo illustrating studio in New York and branched out to photographic title illustrations for silent movies. Famous Players-Lasky Corp., later Paramount, gave Waller the job of doing exclusive title illustrations. In 1922 he was one of the founders of the Film Guild, Inc., an independent motion-picture company which produced five features and three three-reel historical films. These were dramatically successful and financially a loss.

In 1925 he rejoined Paramount as head of the special effects department. When Paramount closed its Eastern studio, Waller became partner in a sales agency for motor boats, William H. Young & Company. Soon he had invented and produced the first water skis and personally tested them. From 1929 through 1936 he was with Paramount again to produce and direct 235 one-reel short subjects.

By 1937 he was interested in the New York World's Fair. He designed the successful projection method for the inside of the Perisphere and he planned and executed the Hall of Color demonstration for the Eastman Kodak Co. At this time he was building his first model for the Cinerama process but he failed to sell it to World's Fair exhibitors who considered it too radical. Out of this came the Waller Gunnery Trainer which used five combat films projected on a hemispherical screen to train aerial gunners in simulated combat conditions. The trainer was credited by the Air Force as averting 350,000 casualties in training and combat.

At the end of World War II, Waller opened a small research laboratory in Huntington, L.I., where he designed and built analyzing apparatus for the Air Force to determine the behavior of bullets fired from fast-moving airplanes. In 1946 he began the construction of the present Cinerama demonstration in Oyster Bay which was first shown operating in 1948. Since 1946 Waller had worked with Hazard Reeves, President of Reeves Soundcraft Corp., to develop stereo sound to accompany the Cinerama picture.

This Is Cinerama, which opened in New York nearly three years ago, has been a continuous success. There are now installations and exhibitions in 10 other cities. Although his gunnery trainer and Cinerama were the most important type among his inventions, in addition to water skis and a photographic measurer of a man for a suit of clothes, he had many other inventions including an automatic photographic timer, a 360° camera and a wind velocity indicator. He was a Fellow of this Society and was the recipient of the Society's Progress Medal last year. Regrettably, he was unable to attend the Pioneers' Dinner during the recent Convention, at which he was one of 26 pioneers honored as having been active since the early years of the Society.

CinemaScope Test Films

As announced by CinemaScope Products, Inc., on December 15, 1953, the distribution of test films would be accomplished by that firm as a service until an authoritative industry group could set up facilities to assure a continued supply.

Through an agreement with CinemaScope Products, Inc., and by establishing production arrangements, the Society has accumulated a complete inventory of test films and has taken over their distribution. The list of these 35mm magnetic four-track CinemaScope test films is:

Code	*Name*	*Description*	*Length, ft*	*Price*
SL-1	Level Balance Test Film	1000 cps; 4 tracks simultaneously; sound only	50	$16.00
MF-1	Multifrequency Test Reel	Various frequencies; 4 tracks simultaneously; sound only	425 (approx.)	70.00
LB-1	Loudspeaker Balance Reel	Recording of identical speech and music on all 4 tracks, progressively in this order: 2, 1, 3 and 4	300 (approx.)	78.00
ST-1	Stereophonic Test Reel	Picture with stereophonic sound and 12 kc control signal.	330 (approx.)	78.00
FL-1	Flutter Test Film	3000 cps; 4 tracks simultaneously; sound only	50	18.75
LP-1	Loudspeaker Phasing Test Film	Warble frequency; tracks 1, 2 and 3 simultaneously; sound only; crossover 400 or 500 cps. Specify which frequency desired.	50	18.75
AZ-1	Constant Level Test Film	8000 cps; azimuth check; 4 tracks simultaneously; sound only	50	11.50
Channel-Four Test film		12,000 cycles/1000 cycles; sound only	50	18.75
Projector Alignment Chart		Picture only	100	10.00

All prices shown are net f.o.b. New York, except for the loudspeaker balance and stereo films which are f.o.b. Hollywood; this price schedule effective May 12, 1954.

Employment Service

These notices are published for the service of the membership and the field. They are inserted for three months, at no charge to the member. The Society's address cannot be used for replies.

Positions Wanted

Motion-Picture Television Technician: 10 yr intensive skill and know-how related to 16-35mm cinematography, animation, recording (optical, tape, disk), editing, laboratory processing practice (black-and-white, color); also kinescope recording techniques; self-reliant; inventive; relocate if required; write: CMC, c/o Penning, 435 E. 74th St., New York 21, N.Y.

Motion-Picture Producer-Director: Now employed in charge of motion-picture production for leading oil company. 18 yrs experience in production, script, direction, motion-picture photography, editing, scoring and recording of industrial, sales training, educational, travel and theatrical motion pictures. Highly experienced in low budget productions for industry. Available in near future; employer has been notified of desire for change to better position. Address inquiries to: A. P. Tyler, Box 2180, Houston, Tex.

Motion-Picture Cameraman: Wants position assisting editor or with production crew. College graduate, film production major, production experience prior to entering Service. Army cameraman for 2 yr in Arctic. Separation from Army July 16, 1954. Will consider temporary position and/or travel. Write Elliott H. Butler, 470 Audubon Ave., New York 33.

Motion-Picture Cameraman, Film Editor: 15 yrs experience all phases of motion-picture work, including research; 3 yrs TV film operations. Developer of Panoramascope wide-screen motion-picture system. Active Member of SMPTE. Desires position with industrial or educational film producer as first cameraman or film editor. Wire: Frank E. Sherry, Jr., 207 West Rusk St., Tyler, Tex.

Photographic Engineer: M.A.; age, 28. Desires challenging, responsible position where technical knowledge and ingenuity will be fully utilized; 8 yrs diversified experience pertaining to the photographic process, with particular emphasis on photographic instrumentation for data recording. Background includes a thorough working knowledge of electronics, the graphic arts, color, machine-shop practice, high-speed photography, etc. Presently engaged as a senior member of a well-known industrial research organization where all kinds of photographic techniques are used as research and service tools. Willing to relocate. Write: P.O. Box 259, New York 36.

Cameraman and special effects producer: For news, educational or advertising films; technical and musical education; camera and 35mm film strip and color development experience. Write: Vitold Bredshnyder, 812 N. Monroe St., Monroe, Mich.

Positions Available

Motion-Picture Sound Mixer (male), GS-10: Require $5\frac{1}{2}$ yr experience in sound mixing for radio, disk recording and motion-picture production, of which at least 3 yr must have been in mixing for motion-picture production, include experience with live dialogue, narration, music, sound effects, lip synchronization and re-recordings. $5500/yr. Obtain Form SF 57 at any first class Post Office or Government Agency; forward or deliver completed to Civilian Personnel Div., Signal Corps Pictorial Center, 35-11 35 Ave., Long Island City, N.Y.

Motion-Picture Asst. Director (male), GS-10: Require $5\frac{1}{2}$ yr progressively responsible experience in motion pictures, theatrical, television broadcast or radio broadcast production which has demonstrated the ability to perform in this position. Included in general experience must be at least $2\frac{1}{2}$ yr experience as a first assistant director in motion-picture production. $5500/yr. Obtain Form SF 57 at any first class Post Office or Government Agency; forward or deliver completed to Civilian Personnel Div., Signal Corps Pictorial Center, 35-11 35 Ave., Long Island City, N.Y.

Photographer (Motion-Picture Animation), GS-9: Require 5 yr experience in photography, 4 yr of it as animation photographer in production of cel animation work in motion-picture production. Also included must be at least 1 yr in technical animation photography. $5060/yr. Obtain Form SF 57 at any first class Post Office or Government Agency; forward or deliver completed to Civilian Personnel Div., Signal Corps Pictorial Center, 35-11 35 Ave., Long Island City, N.Y.

Chicago Film Studio needs man to take charge stop-motion and animation dept. Must be experienced, able to direct title and animation cameramen. Write giving experience and salary desired. Filmack Corp., 1327 S. Wabash Ave., Chicago 5, Ill.

Permanent Employment: Open for mechanical engineers or physicists with at least 1 yr optics experience. Knowledge of camera mechanism, auxiliary timing apparatus and control equipment, precision camera mounts, photography and a general overall knowledge of fundamental optics highly desirable. Positions are located near Cocoa, Fla., at RCA Missile Test Project. Send completed résumés or requests for applications to Harold D. Storz, Employment Sec., RCA Service Co., Box 11, O M U, Patrick AFB, Fla.

Meetings

American Physical Society, July 7–10, University of Washington, Seattle, Wash.

National Audio-Visual Convention and Trade Show, Aug. 1–4, Conrad Hilton Hotel, Chicago.

University Film Producers Association, Annual Meeting, Aug. 16–20, Ohio State University, Columbus, Ohio.

Biological Photographic Association, Annual Meeting, Aug. 25–27, Chalfonte-Haddon Hall, Atlantic City.

Illuminating Engineering Society, National Technical Conference, Sept. 12–16, Chalfonte-Haddon Hall, Atlantic City, N.J.

2d International Symposium on High-Speed Photography, Paris, September 22–28, 1954. Arranged by the Association Française des Ingénieurs et Techniciens du Cinéma. Applications or inquiries should be addressed to the Secretary of the Organizing Committee, P. Naslin, Laboratoire Central de l'Armement, Fort de Montrouge, Arceuil (Seine), France.

National Electronics Conference, Tenth Annual Conference, Oct. 4–6, Hotel Sherman, Chicago.

Photographic Society of America, Annual Meeting, Oct. 5–9, Drake Hotel, Chicago, Ill.

American Institute of Electrical Engineers, Fall General Meeting, Oct. 11–15, Chicago, Ill.

76th Semiannual Convention of the SMPTE, Oct. 18–22, Ambassador Hotel, Los Angeles

77th Semiannual Convention of the SMPTE, Apr. 17–22, 1955 (next year), Drake Hotel, Chicago

The International Commission on Illumination is to hold its next international conference in Zürich, Switzerland, June 13–22, 1955 (*next year*). Offers of papers should be addressed to the Chairman of the Papers Committee (A. A. Brainerd), 1015 Chestnut St., Philadelphia 7. Manuscripts must be in the hands of the Central Bureau between Oct. 1 and Dec. 31, 1954.

78th Semiannual Convention of the SMPTE, Oct. 3–7, 1955 (next year), Lake Placid Club, Essex County, N.Y.

Photographic Society of America, 1955 Convention, Oct. 5–8, 1955, Sheraton-Plaza Hotel, Boston, Mass.

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American Standards — by numbers

No.	*Title*	*Page, issue*
PH22.2-1954	35mm Sound Motion-Picture Film—Usage in Camera	390, May
PH22.3-1954	35mm Sound Motion-Picture Film—Usage in Projector	390, May
PH22.5-1953	Dimensions for 16mm Film, Perforated Two Edges	84, Jan.
PH22.12-1953	Dimensions for 16mm Film, Perforated One Edge	84, Jan.
PH22.17-1954	Dimension for 8mm Motion-Picture Film	390, May
PH22.21-1953	8mm Motion-Picture Film, Usage in Camera	252, Mar.
PH22.22-1953	8mm Motion-Picture Film, Usage in Projector	252, Mar.
PH22.36-1954	Dimensions for 35mm Motion-Picture Positive Raw Stock	390, May
PH22.42	Proposed, 16mm Sound-Focusing Test Film	164, Feb.
PH22.45	Proposed, 16mm 400-Cycle Signal-Level Test Film	164, Feb.
PH22.57	Proposed, 16mm Buzz-Track Test Film	164, Feb.
PH22.75-1953	A and B Windings of 16mm Film, Perforated One Edge	173, Feb.
PH22.88	Proposed, Magnetic Sound Specifications for 8mm Motion-Picture Film	164, Feb.
PH22.90-1953	Aperture Calibration of Motion-Picture Lenses	173, Feb.
PH22.93-1953	Dimensions for 35mm Motion-Picture Short-Pitch Negative Film	84, Jan.
PH22.94-1954	Slides and Opaques for Television Film Camera Chains	390, May
PH22.98	Proposed, 35mm Magnetic Flutter Test Film	164, Feb.
PH22.99	Proposed, 35mm Magnetic Azimuth Alignment Test Film	164, Feb.
Z57.1-1954	Method for Determining Flutter Content of Sound Recorders and Reproducers	399, May

Reaffirmed American Standards — by numbers

The following were announced in the Feb. 1954 *Journal*, p. 164, as reaffirmed without change, except for that of the designation PH instead of Z. References are given for the last full publication in the *Journal*.

No.	*Title*	*Page, issue, year*
PH22.27-1947	Method of Determining Transmission Density of Motion-Picture Films (includes Z38.2.5-1946)	283, Mar. 1948
PH22.37-1944	Raw Stock Cores for 35mm Motion-Picture Film[1]	262, Sept. 1946
PH22.46-1946	16mm Positive Aperture Dimensions and Image Size for Positive Prints Made From 35mm Negatives	298, Apr. 1946
PH22.47-1946	Negative Aperture Dimensions and Image Size for 16mm Duplicate Negatives Made From 35mm Positive Prints	299, Apr. 1946
PH22.60-1948	Theater Sound Test Film for 35mm Motion-Picture Sound Reproducing Systems	539, Nov. 1948
PH22.62-1948	Sound Focusing Test Film for 35mm Motion-Picture Sound Reproducers (Laboratory Type)	541, Nov. 1948
PH22.65-1948	Scanning-Beam Uniformity Test Film for 35mm Motion-Picture Sound Reproducers (Service Type)	542, Nov. 1948
PH22.66-1948	Scanning-Beam Uniformity Test Film for 35mm Motion-Picture Sound Reproducers (Laboratory Type)	543, Nov. 1948
PH22.67-1948	1000-Cycle Balancing Test Film for 35mm Motion-Picture Sound Reproducers	545, Nov. 1948
PH22.69-1948	Sound Records and Scanning Area of Double Width Push-Pull Sound Prints, Normal Centerline Type	547, Nov. 1948
PH22.70-1948	Sound Records and Scanning Area of Double Width Push-Pull Sound Prints, Offset Centerline Type	548, Nov. 1948

(See also Jan. 1954, p. 91 for listing of Standards for Still Photography.)

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