F. H. RICHARDSON'S HANDBOOK OF PROJECTION

5TH EDITION

The Blue Book of Projection

SOUND RECORDING REPRODUCTION AND PROJECTION

A Chalmers Publication

RICHARDSON'S HANDBOOK OF PROJECTION

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FIFTH EDITION

In Three Volumes

VOLUME III

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Author's Note

ALL matter dealing with equipment, the use of equipment or with technical matters which is contained in this work, has been examined by and has the approval of the engineering department of one or the other of the equipment manufacturers or producers concerned. You may therefore feel assured that in so far as has to do with equipment and technical matters, everything herein contained was correct at the time of its compilation.

However, let it be clearly understood that since new equipment is involved, and new theories as well, with both still in some measure in the formative stage, **changes and improvements which may alter the correctness of some sections of such a work as this cannot be wholly guarded against.**

It will be said, however, that it is not the intention to include those things which seem likely to be subject to much change.

It will be noted that I have included in this work certain articles descriptive of various elements of sound apparatus already published in the projection department of the *Exhibitors Herald-World, The American Projectionist* and in *Movietone Bulletin,* of which publications the author of this book is, at this writing, editor. For this no apology is either necessary or offered. The information and instruction contained in those articles is essential to the completeness of a work of this sort, and I feel that they could not be materially improved upon as originally written. You will now have them in convenient bound form for reference and further study.

Important Notice

Electric Current Action

IN this work I shall adopt the latest theory of electric action, which holds that what we term electric current consists of minute particles of negatively charged electricity called "Electrons." Current flow is the movement of these particles. They flow or move from negative to positive, and not from positive to negative as was the formerly accepted theory.

I am not proposing to take any part in any argument as to whether this theory is right or wrong. I merely am telling you it is now the theory accepted by scientists, hence we shall use it in this work. I make this explanation from the fact that at the time the Bluebook was compiled the positive-to-negative electrical movement was still held to be correct. The acceptance of the new theory is very recent.

I commend this, my latest work, to projectionists, with full confidence that it will be welcomed and approved by them. It will be revised and improved from time to time, as may seem necessary.

F H Richardson

A Monument

THE marvelous results attained in perfection of sound in synchronization with motion as applied to motion pictures is literally an outstanding monument to the genius of mankind, and particularly it is a monument to those scientists and engineers who have, by years of hard work devoted to tremendously difficult research, with perseverance almost unbelievable, made it possible.

In this we have no particular system in mind, but are considering the thing as a whole. In the beginning of motion pictures certain men did much to make the then world-wonder possible. No one then saw fit to record the facts, and now we do not know, and have no way of ascertaining from reliable records which ones of the many conflicting claims are true and which are false.

Successful synchronization of sound with motion, as applies to motion pictures, was a world event. I believe the names of those men whose genius and long extended efforts have made the thing possible should be recorded while we still have the main facts fresh in memory. The very best type of men do not work for money alone. They do not work for glory alone either. In many outstanding instances the force which drives them is pure love of or for accomplishment. It is such men as these who make for true progress of the human race. Often and often they work out problems which mean much to humanity and to human progress, turning immediately to other problems while selfish men commercialize their accomplishment, not infrequently reaping fortunes, and even appropriating credit for the creation itself.

This is not fair! It is not right! It is not decent! These men may or may not seek glory. However it is but natural they would like at least to have credit for their accomplishment and it is but right and decent that they have it.

I want you men to know, and I want to now set down the names of such men as I have been able to ascertain positively had some important part in the evolving of the marvelous thing you projectionists now are called upon to handle. I am unable to set forth in much detail the part each played in the discovery and perfection of sound recording and reproduction in synchronism with motion as applied to motion pictures, but I do know that each did play a part, and an important part, too.

The great genius of the age, Thomas A. Edison, discovered the basis of the one thing which makes it possible to record and reproduce sound as we are now doing in theatres. In the year 1887 Mr. Edison, in an endeavor to increase the longevity of the carbon filament lamp, made certain experiments with some incandescent bulbs in which two carbon filaments had been installed.

In the course of these experiments, in charge of which was a man by the name of William Kennedy Laurie Dickson, then a member of Mr. Edison's research staff, it was discovered that when current was sent through one filament, the other filament was in some manner excited. Many galvanometer tests were made and it was thoroughly established that the effect really was there, and the experiments were filed away for further investigation.

That effect was what has become known at "The Edison Effect." It is the basis of vacuum tube action, and to that extent Mr. Edison may justly claim precedence over all others in the field of sound recording and reproduction, because up to this time, at least, there is no known substitute for the vacuum tube in sound amplification.

Also, in 1910, Mr. Edison did some experimental work in an attempt to synchronize his phonograph records with motion.

1901—Ernst Ruhmer, Germany	Recorded on film with speaking arc, incandescent lamp and glow discharge tube.
1904—E. Gehrcke, Germany	Co-worker with Ruhmer in the recording of alternating current phenomena photographically.
1906—R. T. Haines, England, and E. A. Lauste, England	Patented system of recording and reproducing sound and pictures simultaneously.
1907—J. F. Dirzuwert, U. S.	Optical phonograph and system for recording and reproduction.
1913—E. E. Ries, U. S.	Preliminary work of recording sound on film using the "Speaking arc." He realized necessity of small slit to improve quality of recorded and reproduced sound.
1913—S. O. F. A. son Berglund, Sweden	Optically recorded talking pictures.
1915—H. B. Stocks, England	Photographic sound record using mercury arc.
1916—C. E. Fritts, U. S.	Disclosure of general system of sound recording and reproduction in U. S. Patent 1,203,190.
1919—A. O. Rankine, England	Film recording with optical shutter.
1921—L. DeForest, U. S.	Developed and perfected method of recording sound on film and reproducing same.

1919—Joseph Engl, Germany..Developed system of talking pictures very similar to DeForest and Case.

1918—T. W. Case, U. S., and E. I. Sponable, U. S..Developed photo-electric cells recording lights and generally made commercial the present system of recording sound on film.

1925—J. P. Maxfield.........Later work on disc synchronized with film.

Please let it be clearly understood that this list makes absolutely no claim to completeness, but only that these are the names of at least some of the known pioneers in the work.

ALL technical matter appearing in this volume has been examined by the Engineering Departments of the respective companies concerned, and has their approval.

ALL matter contained in this work which pertains to Western Electric sound recording and reproduction equipment has been examined and is approved by the Western Electric Company and the Electrical Research Products engineering staffs.

H. B. Santee

Director of Theater Engineering.

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Sound Projection in Synchronization with Motion

IT is with considerable trepidation that I have approached the task of preparing a Sound Volume to the Bluebook of Projection. The work has only finally been taken up because of the insistent demand of Bluebook users and at the request of my publishers, who it seems also have received many requests and demands for such a work.

It is only very recently that I have considered either methods or equipment as sufficiently stabilized to warrant putting instructive matter into book form. Up to very recently changes and improvements were being made with such rapidity in all makes of sound equipment that anything put into print one month might, and very probably would, be more or less wrong and out of date next month. Under these conditions I declined to issue a Bluebook Sound Volume.

However, things have now settled down to a fairly firm basis, so that while improvements and changes must still be reckoned with, still there is considerable available in the way of reliable instruction upon sound projection and sound equipment which will remain essentially correct, regardless of changes in the apparatus itself.

Moreover, the fact that sound equipment is being installed in a very large and rapidly increasing number of theatres cannot be ignored and makes it imperative that all possible reliable, available information and instruction be supplied the men now handling sound equipment, or who soon will be called upon to handle it. They, in fact, have the right to expect, and even to demand, that this be done. Everything considered, therefore, this work has been undertaken, and will be made as complete as it is possible to make it.

It would be very easy to compile a mass of general radio matter, written in engineering terms, and thus make a bulky, showy volume. I am including no such matter, however, because I do not regard that sort of thing as either honest or efficient. This is not a radio book. It is a sound-in-synchronization-with-motion book, and while there is of course a considerable similarity, in a general way, between it and radio, still the fields are wholly separate and their problems for the most part entirely different.

In this book the various systems now in use will be dealt with, and the matter concerning each of them will be examined by and have the approval of their engineering department, insofar as has to do with technical matters. You may therefore know that what you find herein along these lines is correct at the time of its writing.

First of all let us discuss the differences in requirement as between silent picture projection and the projection of silent pictures (all pictures are really, of course, "silent") with synchronized sound accompaniment. Let us consider, whether or not, more is demanded of men engaged in one than in the other; whether or not all those who have been able to hold their own in the silent picture projection field may reasonably expect to be successful in synchronized sound projection.

The silent picture projectionist has charge of apparatus which is, by comparison with sound projection equipment, very simple. The problems incident to silent picture projection are, by comparison, not nearly so difficult as are those of sound projection.

However, when the silent picture projectionist has graduated into a sound projectionist, he still will have all the equipment and all the projection problems he had before. He must perform every duty he performed before. Nothing has in any degree changed with regard to picture projection, but in addition he is called upon to reproduce and project sound, which involves the use and care of highly sensitive, complicated equipment.

It therefore would seem idle to say the problems of the projectionist are not vastly augumented, and his work made very much more difficult by the advent of synchronized sound. It would seem rather foolish to assume that a very much higher grade of expert knowledge is not required and demanded of the sound projectionist than of the projectionist of silent pictures, provided each is to work efficiently and well. It also is evident that men cannot hope to really make good in sound projection unless considerable time and energy is devoted to the study of technical matters pertaining to it.

One very important difference between silent picture projection and the projection of what has now come to be familiarly known as the "Talkies," lies in the fact that the silent picture story is read from the action, supplemented by occasional explanatory sub-titles, so that but one sense, the sight, is employed.

Without a synchronized sound accompaniment, projection faults, while in themselves harmful and bad, did not and do not seriously interrupt the continuity of thought in following the story. In fact, the mind might well be so engrossed in the story that any except a very serious projection fault would pass almost entirely unnoticed.

With synchronized sound added, however, the situation is altered. Two senses must be employed, namely sight and hearing, and the latter is very sensitive to fault. Faults in sound will not be passed over unnoticed. They will be instantly and objectionably apparent to the audience. A moment of thought will, I am sure, convince you of the correctness of that statement, and if it is correct, then it naturally follows that a very great deal more painstaking care, a much higher grade of work and much more of expert knowledge is demanded and required from the sound-picture projectionist than from the one who projects silent pictures only.

The conclusion that faults in projection must be reduced to the minimum with the advent of sound is further emphasized by the fact that, as time goes on, it is but reasonable to suppose that sound in synchronization with motion pictures will more and more attract the really great ones of histrionic art to the screen. In the past the projectionist has been able to work great harm to the performance of those whose chief claim to "fame" has been to pose effectively, wear a minimum of drapes in public or to vamp well, without serious protest from anyone. But when it comes to thus outraging both the person and the voice of real artists, thus causing them to appear foolish before audiences, we may fairly assume that it will not pass either unnoticed or unrebuked.

From any and every angle it is safe to assume that the advent of synchronized sound will result in the demand for far more careful work in projection. Certainly it sounds the doom of the "machine operator," because by no stretch of imagination is it possible to regard synchronized sound projection as being merely the matter of "operating a machine." Rather it is the handling of complicated, highly sensitive equipment, and the reproduction of life-like effects in both pictures and sound projection upon theatre screens. It seems but reasonable to presume it will literally demand the projectionist to treat projection as in the nature of a profession, and to study its technique.

BASIC PRINCIPLES.—As has been intimated, in order to efficiently handle any sort of equipment, it is vitally necessary that the underlying principles upon which it depends for its action be clearly understood. This statement or fact applies especially with force to sound reproducing and projection equipment. If, for example, we do not understand in what manner an amplifying tube functions, then its action is to us a dense mystery, and we are more or less afraid of it. We do not undestand its action and only know that in some mysterious way it increases the volume of sound.

No man can work understandingly and efficiently with anything he does not understand. The more thoroughly a man who must work with and handle any piece of apparatus understands it in all its parts, including the basic principles upon which it depends for its action, the better he can work with it, and the better the general results he will get from it. As well dispute the fact that the sun rises in the east as to dispute that statement.

However, once we understand the basic principle upon which the amplifying tube depends for its operation, the whole thing becomes quite simple. All fear of it is instantly lost. For instance, when we turn the fader knob we know exactly what takes place within the tube, and as soon as we also understand the action of the fader, we know just why it takes place. We then begin to understand what can and what cannot be done with amplifier tubes. In short, we are in position to handle and work with them intelligently, and INTELLIGENT WORK ALWAYS IS EFFICIENT WORK.

It is my intention in this work, in so far as is humanly possible, and in language the non-technical man can understand, to give you an understanding of the underlying principle upon which every part of sound reproducing and projection equipment depends for its action. I shall try to tell you and show you what makes each part work, and just how it works, as well as the relation of each part to other parts of the apparatus. It is a very large task, but I shall try my best to do it to your satisfaction.

From Sound to Electric Current

LET us next discuss sound. Let us see just what it is, how it is produced and how it is changed from its original form into an electric current capable of operating the sound recording apparatus.

The vocal cords of the human throat, or of an animal's throat, the reėds of an organ or its pipes, the base or snare drum or anything else capable of producing the thing we call "sound," does so by setting up vibrations in the atmosphere, which travel through the air until they encounter, for example, the drum of our ear, causing it to vibrate, and thus transmit to our brain the sensation we call "sound." Briefly that is how sound is produced and how it passes through the air in the form of air vibrations called sound waves.

In recording sound for the purpose of reproduction in synchronization with motion pictures, an instrument of enormous sensitivity is used, called a "microphone." Its operation is essentially as follows:

The sound waves striking the microphone diaphgram, made of a metal called duralumin from one to two thousandths of an inch thick, and therefore highly sensitive to vibratory impulses, cause it to vibrate with rapidity exactly equal to the rapidity or "frequency" of the sound vibrations or waves themselves. If the sound be low pitched, as that of a piano bass note, then the vibrations (frequency) per second will be low. If the sound be high pitched, as, for example, a shrill whistle, then the frequency (vibrations per second of or in the air) will also be high. Between the lowest and the highest are thousands of possible variations.

Get this fact clearly: The tone and quality of sound is entirely dependent upon the combinations of frequencies of the waves set into motion in the atmosphere by the vibrating element of the thing producing the sound. As the frequency (number of vibrations, or waves per second set up in the air by the thing producing the sound) increases, the pitch of the sound, as heard by the ear, increases, or is raised, and vice versa.

I have put this in various forms of words, to the end that there be no misunderstanding of the matter. It is a basic principle, and must be clearly understood if one is to understand the action of sound recording and reproducing apparatus.

As I have said, the sound waves traveling through the air cause an exceedingly thin metal plate or disc, called the "diaphragm" of the microphone to vibrate with a speed exactly equal to their own, which same is of course varying constantly with each change or modulation of sound, no matter how slight.

I have no apologies to make for repetition in these matters. It is absolutely essential to an understanding of the action of sound recording and reproducing equipment that you have a clear understanding of them.

In the type of microphone called the "Condenser Type," which is now universally used for recording, the diaphragm forms or is one plate of an air condenser. By "air condenser" it is meant that the plates (see "The Condenser," page 1017) are insulated from each other by air. The other plate is in the form of a flat metal disc of considerable thickness. The two are separated by from one to two thousandths (.001 to .002) of an inch. The back plate is anchored in fixed position. It remains rigid and immovable.

Under this condition it may readily be understood that any back and forth movement (vibration) of the front plate (the "diaphragm") caused by the impact of the sound waves in the air upon it, will result in a change in the distance of separation between the two, the amount of depth of vibration, and therefore the variation in distances of separation, being directly dependent upon how much movement any sound wave causes or sets up in the diaphragm. It will also be understood that the amount of movement any wave will set up in the diaphragm will be in proportion to the force exerted by that wave, which is governed entirely by the acoustic energy of the source originating the wave.

That much seems understandable enough, and when we consider that each variation in air wave frequency, no matter how slight, will cause variation in rapidity of diaphragm vibration, we begin to see a bit further into this mysterious thing.

If you have done as I have advised, and studied the matter under "The Condenser," page 1017, you will know that each difference in the separation distance of the plates of a condenser, no matter how slight, has the effect of altering the capacity, or in technical terms the "capitance" of the condenser, which is another step in advance in understanding this matter.

We will now proceed to take the final step. If we connect the two condenser plates to a source of E. M. F., such as, for example, a storage battery, one plate to each polarity, and set the condenser plates vibrating by means of sound waves, the condenser will have its capacity altered with every variation of separation distance, hence it will be charging and discharging constantly as the diaphragm vibrates with the sound waves, and this charge and discharge will induce or set up in the circuit so attached a weak alternating current, which will have a frequency exactly equal to the frequency of the sound waves, and a strength exactly in proportion to the strength of the sound waves, which means in exact proportion to the acoustic energy of the source from which those sound waves originated.

In other words we shall have an alternating current which is the exact replica, in electrical form, of the sound waves which formed it, assuming, of course, that the equipment is itself such as will give perfection in transposition from sound to electric, and that it be handled in a manner which will cause it to function perfectly.

Because of the weakness of these electrical impulses, or as the engineers would say, because of the low energy level of this current, it is given one stage of amplification right at the microphone in order to prevent possible interference by stray currents on its way to the main amplifiers.

The wires from the "mike" connect to the amplifying panel, where the current strength is amplified approximately one hundred million (100,000,000) times before being used to operate the recording apparatus.

I believe you now have a fairly competent understanding of the means by which sound is made available, in the form of electric current, for the operation of the recording apparatus. *This method does not vary, regardless of what recording method is employed.*

That is the story, then, of how the vibrating element of a human throat, called the "vocal cords," the vibrating element of a musical instrument, or anything else capable of setting up sound waves, does set them up of varying acoustic energy and frequency; how these waves or vibrations travel through the atmosphere, strike or impinge upon the surface of the very highly sensitive microphone diaphragm, operate that diaphragm, and by the action of the condenser of which it forms a part, transforms the air waves into electric vibrations in the form of an alternating current capable, after amplification, of operating equipment capable of recording the electrical vibrations so set up upon either a motion picture film or a phonograph record, in such manner that they may be again "picked up" and reproduced in a manner little short of marvelously perfect.

If you do better work when the boss is watching, you are a very poor man to have on the pay roll.

Any boob can get some sort of screen results. But real ability is required to get the best that can be gotten from the equipment provided.

Recording Sound

LET us next discuss sound. Let us see just what for recording sound, three of which are now in sufficient use to justify having our attention.

By two of these methods the sound is impressed photographically upon a narrow band of the film at one side of the picture frames. The sound and the picture therefore, being on the same base, it is impossible to seriously interfere with perfect synchronism of sound and motion.

The third system records the sound upon what amounts to a phonograph disc record. With this latter system it is always possible that synchronism may be seriously interfered with.

Regardless of what system is used, the recording of sound in synchronism with motion pictures in itself presents difficulties of large dimensions, aside from the mere task of recording. That this is true we readily see when it is considered that in the recording of productions, of musical numbers, of monologues and many or even most other things, it is essential to pleasing results that all sounds except those the audiences are supposed to hear be excluded from the record.

This means that since extraneous sounds would work harm to, for example, productions in which dialogue is used, the studio in which such productions are made must be as nearly soundproof as possible. If located in a city, then all noises from, and vibrations caused by, pass-

Figure 381 (Interior of Studio).

This particular studio is located in New York City, close to a heavy traffic, cobble-paved street, and right beside another street through which trucks and automobiles pass all day, yet neither vibration or sound finds its way into it.

ing cars, trucks, et cetera, must be shut out. The studio walls, ceiling and floor must have sound absorbing coverings to avoid sound reverberations. Even the noise incident to operation of the camera mechanism must be prevented from reaching the "mike."

There are two methods of sound recording upon films in use at the present time. One is known as the "Variable Density," which is employed by Fox Movietone, DeForest Phonofilm, Powers Cinephone and others. The other method is known as the "Variable Area." It is used by RCA Photophone and others.

It is not the function of this work to make comparisons of relative excellence of methods. It would be highly presumptuous to attempt to do so. It may, however, be remarked that both these methods give splendid results when properly handled.

In describing the Variable Density method of recording, I shall use the Fox Movietone as my example, it having been the first successful and at this time (1929) the most widely used sound-on-the-film method in use in theatres.

As you all doubtless know, Fox Movietone impresses the sound photographically upon a strip of film beside the picture frames, on the right hand side as the film is threaded into the motion picture projector. This strip, which we will call the "sound track," is one-tenth (1/10) of an inch wide. It of course reduces the picture width by one tenth of an inch, though the depth of the "frame" is not affected.

The process of recording is as follows: The negative film passes the camera aperture in the usual manner at a speed of exactly ninety feet of film per minute. The scene, but not the sound is there impressed upon it, just as it is with silent pictures.

The film then passes down past the aperture and is threaded into and passes through another "gate," in which is a very much smaller aperture, and as the portion representing the sound track passes over this aperture it is exposed to light from an "Aeo" lamp, which, acting just as the sunlight does in an ordinary camera, impresses the sound upon the film, though that is by no manner of means all the story.

The microphone which is to receive the sound vibrations it is desired to record may be placed at any desired point, close to or far distant from the camera. The wires from the microphone, commonly known as the "mike," connect directly with the main amplifying panel. The amplifying panel is in turn connected with an "Aeo" lamp, which, acting through a slit system exactly similar to that described further along (see page 1104), illuminates a space approximately one one-thousandth (.001) of an inch high by one-tenth (1/10) of an inch wide. Put in different form, the Aeo lamp projects to the sound band, through a special lens system and a "slit," a line of light of the dimensions before indicated.

This illumination occurs just fourteen and one-half (14½) inches from the center of the picture aperture, which means that the sound record accompanying any one picture frame is opposite the frame 14½ inches, or 19⅓ frames from it and "beyond" it. In other words it is made opposite a frame of pictures located 19⅓ frames or 14½ inches before the sound impression itself.

As I have told you, the current set up by the microphone which, by the way, is energized by a 200-volt storage battery, operates the Aeo lamp affixed to the camera after being amplified approximately 100,000 times at the amplifying panel. **It therefore follows that since the power of the current which operates the lamp fluctuates exactly with, and in exact proportion to every fluctuation of the sound wave frequency, the brilliancy of the Aeo lamp, and therefore the brilliancy or illuminating power of the light it projects to the film through the slit varies in exact synchronism with and in exact proportion to the sound wave frequencies or intensity,** with result that the sound band of the negative film is illuminated in exact proportion to the modulations of sound.

THE AEO LAMP.—The Aeo lamp used in recording sound is not a filament lamp. It consists of a glass bulb in which are fixed a small metal plate and a loop of platinum wire coated with alkaline earth oxides, located with reference to each other somewhat as shown in Fig. 382.

The Aeo lamp bulb is filled with Helium gas. The plate is positive and the loop negative. When in action, they are energized by a battery of about 350 volts, which causes the gas surrounding the plate to glow with a faint pink color, and the gas surrounding the loop to become very brilliant, the color being an intense light blue. This is the light source utilized for illuminating the film through the slit. However, all this would be useless without going further, because the light would be of even, unvarying intensity.

Examining the diagram Fig. 382, you will observe that circuit F attaches to the Aeo lamp circuit. Circuit F is the circuit connected, through the amplifier panel, to the microphone. It carries an A. C. current representing,

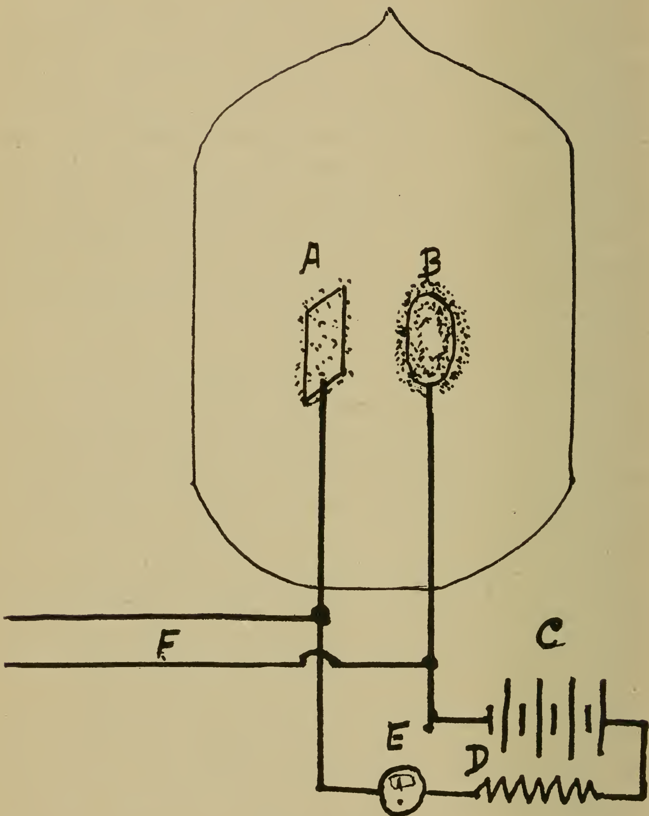

Figure 382.

This is only intended to illustrate the lamp parts and circuit. No attempt has been made to observe relative proportions in the diagram. A—Plate. B—Loop. C—350-volt battery. D—10,000 ohms resistance. E—Ammeter. F—Circuit to amplifier and microphone.

in its variations, the sound wave frequencies, and is able to and does impress those variations upon the Aeo lamp circuit in such manner that the light brilliancy of the gas surrounding B, Fig. 382, varies in exact proportion, or in exact frequency with the sound wave frequencies.

It is very difficult for you and I to grasp the fact that such an action can be set up with such astounding perfection that all the vast number of sounds and sound combinations can be faithfully impressed upon the film sound band in photographic form, but the splendid results Movietone has shown is something more than abundant proof that it is so.

The hard thing to grasp is the fact that the brilliancy of a light source can possibly vary so fast, but the Aeo lamp is another product of inventive genius produced with exactly that end in view, and it does so vary, incredible as it may seem. The proof is found in the marvelous faithfulness with which sound is reproduced by this process.

Returning to the "slit," it is so placed and microscopically adjusted that it projects a line of light approximately one one-thousandth (.001) of an inch thick by one-twelfth (.080) of an inch wide upon the sound band, at precisely right angles to the length of the film, or to the edge of the film if that is more readily understood.

Remember that in the camera sound gate the film runs continuously, and this line of light is shining continuously upon the sound band, but with constantly varying brilliance. Of course you all know that the amount of discoloration upon any point of the negative film will, after development, be dependent upon the brilliancy of the light reaching it during exposure and the length of exposure. If the light be brilliant, or the exposure long, then the resultant discoloration will be relatively great. If the light be dim, or the exposure short, then the discoloration will be relatively slight, these values being exactly reversed in the printing of the positive.

That is just plain photographic lore now, I think, fairly familiar to all. It then follows that when the negative film has been developed, the sound band will vary in density constantly and, since the time of exposure is fixed and constant, in exact proportion to the brilliancy of the light to which it has been exposed; in other words, in exact proportion to the brilliance of the Aeo lamp at any instant of time.

This being true, then, since the sound wave vibrations control the variations in filament brilliancy, it follows that what we have on the sound band after development, is an exact photographic representation of the sound wave frequencies, or, in other words, of the sound itself.

In Fig. 383 we have a section of the Movietone sound band magnified thirty (30) times. Note the shadings from dark to light, and vice versa. Each difference in density means a difference in sound. In considering this photograph, remember that it represents a section of sound band only about three-sixteenths (3/16) of an inch in length, so that you see these wide "lines" actually occupy less than one-sixty-fourth (1/64) of an inch of space, up and down, on the sound band.

Fig. 384 is a section cut out of the magnified sound band shown in Fig. 383, together with a graph showing the percentages of total transmission of light, or in other words the percentages of total light the various shadings

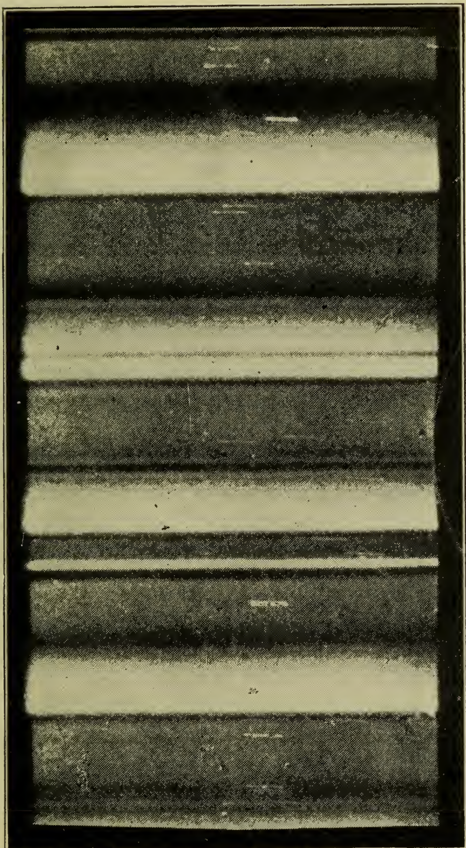

Figure 383.

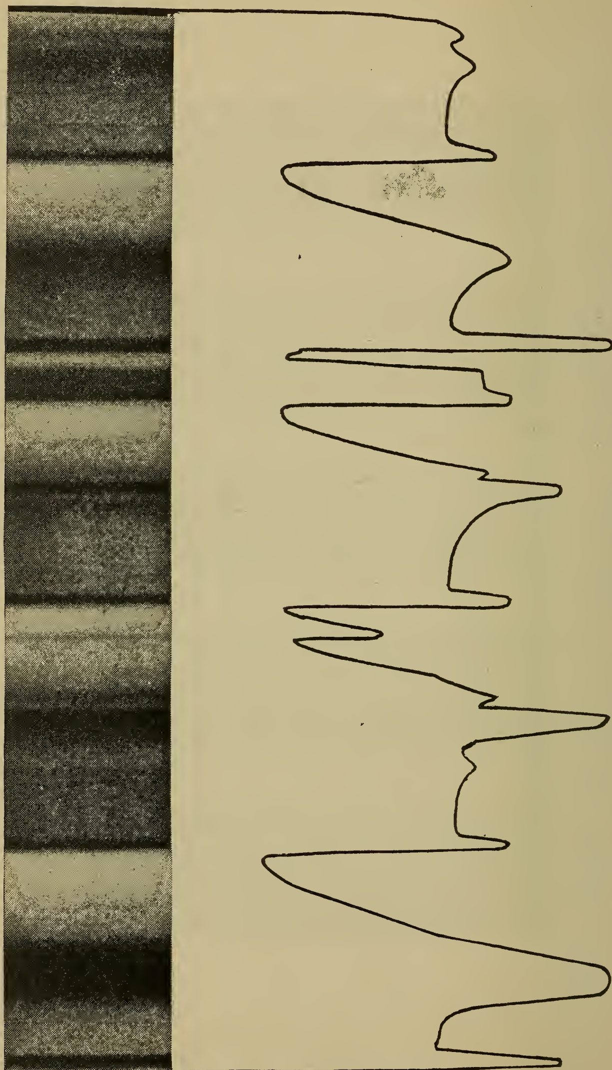

Figure 384.

permit to pass through the film. Remember that the photo-electric cell will be active and set up electro-motive force in the amplifier circuit in exact proportion to the amount of light these shadings permit to reach it.

Considered in that light, there really is small mystery in the action of the sound track. It is made very clear, I think, in an article printed in *Movietone Bulletin.* I shall therefore reproduce it here, because I think it cannot be much improved upon. It is as follows:

"The pressure of sound waves impinging on the diaphragm of a condenser microphone (as distinguished from a carbon microphone), causes the diaphragm to vibrate. The amount of the displacement of the diaphragm is proportional to the intensity or loudness of the sound. This movement varies the capacity of the condenser microphone, thus altering the charge on the grid of a vacuum tube which is connected in series with the microphone. The resulting alternating current is proportional and in phase with the movement of the diaphragm.

"If a carbon microphone is used, the displacement of the diaphragm varies the resistance of the microphone and causes a varying or modulated direct current. This current may be considered as made up of a direct and alternating component.

"After several stages of amplification in which the voltage is increased approximately 100,000 times, it is impressed on an Aeo light. The Aeo light is a gas tube excited by direct current and so designed that its intensity or brightness is proportional to the applied voltage. The light shines through a narrow slit on a moving negative film in the camera and the variations of the light are recorded upon it. The exposure of the film is in phase and proportional to the alternating voltage applied to the Aeo light. Thus the sound track is a record of the exposure due to the variations in brightness of the Aeo light.

"In reproducing, the printed sound track is passed through a narrow light beam, (.001" x .08"), of constant intensity and the transmitted light falls on a photoelectric cell. With proper developing and printing the light transmitted through the print is proportional to the exposure of the negative at the corresponding point. The resistance of a photo-electric cell varies inversely proportionately to the light shining on it. Thus the current flowing through the cell is proportional to the light transmitted through the film. The voltage drop across a series resistance in the cell circuit is impressed on the grid of the first tube of an amplifier. After it has been amplified approximately 100,000 times, this voltage is impressed on a loud speaker and the diaphragm moves proportionately. As the amplification is accomplished without appreciable distortion, the movement of the diaphragm of the loud speaker is proportional to the movement of the diaphragm of the microphone and the sound which was recorded is reproduced.

"We are now in a position to analyze the sound track. If the source of the sound to be recorded has a frequency of 60 cycles, the Aeo light intensity will rise to a maximum, fall to a minimum and return to normal 60 times every second. The film moves 90 feet per minute, or 18 inches per second. Therefore, on every 18 inches of film there will be found 60 light and 60 dark striations, .15 inches wide. If the frequency were increased to 6000 cycles the width of the striations would decrease to .0015 inches. Thus the width of the band on the sound track is a measure of the frequency of the sound recorded. The difference in shade between the light and dark bands is a measure of the intensity of the sound.

"As most bodies vibrate or tend to vibrate in harmonic motion, the sound waves gradually increase and decrease. Therefore, the striations usually are not sharp but gradually fade from one to another.

"This simple example of recording a single fixed frequency is seldom met in practice. The fundamental frequencies of the human voice vary from 60 to 1300 cycles and the overtones are as high as 10,000. Two musical tones from different instruments of equal intensity and frequency, but of different quality, will differ in the manner in which one striation fades into another. In orchestral recording many frequencies varying over the entire audible range of 20 to 10,000 cycles should be recorded at the same instant. The resulting sound track showing all of the varying frequencies is extremely complex and shows practically no uniformity or regularity.

"The picture, Fig. 384, is that of a strip cut from the center of a sound track and magnified to 30 times its original size. Plotted vertically under it are the approximate corresponding percentage transmissions of total light. As stated during the course of the text, this graph with a variable vertical scale could represent:

(1) The vibration of the diaphragm of the microphone.
(2) The microphone current.
(3) The Aeo light voltage.
(4) The intensity of the Aeo light.
(5) The exposure of the negative.
(6) The transmission of the print.

(7) The illumination of the photo-electric cell.
(8) The photo-electric cell current.
(9) The voltage impressed on the loud speaker.
(10) The vibration of the diaphragm of the loud speaker.

"That, very briefly and without any *technicalities* at all, describes to you the process by means of which variable density sound is impressed upon the film, and supplies you with a view of that type of sound photographic impressions so magnified that you may have a competent understanding of just what the sound band impression lines really look like, though to the naked eye they appear merely as a series of fine lines, often almost entirely invisible."

Observe in Fig. 383, how light gradually shades into dark, or vice versa. That corresponds to or with the back-and-forth movement of the air transmitting the sound waves and the in-and-out movement of the microphone diaphragm, hence the more sudden the change from light to dark or dark to light, the more violent was the back-and-forth movement of the air at that instant of time, hence the greater the acoustic energy of sound. Conversely the less the contrast between light and dark, the softer was the sound recorded.

In considering this you must differentiate between loudness and pitch. A high pitched sound may not be loud, neither is a low pitched sound necessarily a "low" sound. A base drum may make a lot of racket, whereas a child's whistle may be made to sound low.

Disc Record Recording

THE disc record method of recording, which is employed by the Vitaphone Corporation, among others, is very different from the sound-on-the-film method. The "disc record" is really nothing more or less than an enlarged phonograph record, made somewhat differently and with extreme care, playing from inside to outside instead of outside to in, as with phonograph records, and with special markings on both record and film, and a geared synchronization of the record-carrying turntable with the motion picture projector mechanism to insure a continuance of synchronization between sound and action, once it has been established by proper use of the aforesaid markings. These records rotate, both in recording and in reproduction, at 33⅓ revolutions per minute.

The method of recording is exactly the same as with sound-on-the-film up to the instrument actually inscribing the sound record upon the disc. The sound is picked up by a microphone, and transformed into electric current, as already described. It then passes through the amplifiers, as set forth, but there the similarity ceases.

First, however, a bit of explanation concerning the groove on a phonograph record. The general idea is that the record consists of a series of indentations made by the needle point in the bottom of the groove. Put in another way, it is popularly believed that the record consists in or of differences in depth of the bottom of the groove caused by the recording needle vibrating up and down, thus making a series of indentations in the floor of the groove formed by it, which same constitute the sound record. This, however, is not the case here.

Examining a phonograph record under a fairly powerful glass it will be found that the sides of the grooves made by recording needle are not straight. Of course they curve, but that is not what I refer to here. Their sides instead of being a "straight" curve side, wobble or "wiggle" from side to side slightly, and these side-to-side movements constitute the sound record. They are in fact a true profile of the recorded sound wave or vibration.

When you place the needle in a record and start the projector, as the record revolves the needle point, following these undulations in the groove sides, moves slightly from side to side throughout the entire run of the record, and it is this movement which, as will be explained under "Reproduction," page 1109, reproduces the sound. But that is getting ahead of our story.

The record is made as follows: As has been explained, the current reaches the recording apparatus from the main amplifier, just as it reaches the Aeo lamp in film recording. In this case, however, instead of an Aeo lamp fluctuating in brilliance with the sound waves, the phonograph recording needle is, by suitable means not necessary to describe here, made to oscillate from side to side in synchronism with the sound wave frequency. For the method of reproducing the record sound see page 1109.

Light Valve Recording

TWO methods for the recording of sound on the film are now being used in connection with Western Electric equipment, viz.: the Aeo lamp, as already described, and what is called a "Light Valve," in which is employed a fundamental principle of great importance and wide application. It is as follows:

Suppose we have what is called a magnetic field, that is, a space subject to the influence of a magnet, such as, we will say, the gap between the poles of an electromagnet. Now imagine that in this space we hold a conductor, across the direction of the field, a straight piece of copper wire, for example, held in the space between the pole-pieces. Then on passing a current through this wire, the wire will try to move sideways, that is, parallel to the face of the magnet pole. The wire will continue to exert a force, if it be held, or to move if movement be permitted, as long as it stays in the magnetic field and the current keeps flowing. If the direction of the current is reversed, the direction of the force or movement is also reversed.

This simple principle, or method of obtaining force and motion by electrical means, is utilized in some form in all the electric motors in the world, from those that drive fans and dentists' drills to those that propel battleships and haul the transcontinental trains over the Rocky Mountains. It is also the basis of the dynamic loud speaker, of the oscillograph, and of some types of galvanometers. Its use in the Western Electric light-valve recording machine is almost exactly in the simple fundamental form just described.

In this machine, a powerful electromagnet with tapered pole-pieces creates an intense magnetic field in the space between its poles. Stretched side by side across this space are two tiny flat ribbons of duralumin a few thousandths of an inch thick. These ribbons lie so close to each other that only two-thousandths of an inch separates their adjoining edges.

Under this condition, on passing a current up one ribbon and down the other, they will both move sideways, but, be it noted, in opposite directions, because the current is flowing through one in the opposite direction to what it is flowing in the other. The result is that with current flowing one way, the ribbons come closer together; the other way, they separate further apart. Therefore the alternating current which represents sound waves causes them to vibrate, and the separation between them increases and decreases correspondingly with the back and forth movement of the air in the sound waves.

An opening is provided in each pole face, opposite the separation between the ribbons, therefore if a light be caused to shine into one opening, the width of the beam that passes through will depend on the separation of the ribbons.

In film recording by the variable density method the basic problem is to vary the exposure of the sound track in accordance with the frequency and loudness of the recorded sound. Photographic exposure can be varied either by changing the intensity of the illumination or by changing the duration of exposure. The former method is, of course, the one followed with the Aeo light or, as it is called, the "flashing lamp" method. The latter is the basis of "light value" recording, the action being as follows: The separation between the aforementioned stretched metallic ribbons is ordinarily two-thousandths of an inch. By means of a 2 to 1 optical reduction through lenses, a beam of light passing between the ribbons when they have this separation is made to appear on the sound track as a line one-thousandth of an inch wide. Therefore, when the film is passing through the recording machine at its standard speed of 90 feet per minute, or 18 inches per second, each point on it gets an exposure of 1/18,000 of a second. Now suppose that we put the light valve in action recording a sound of a certain intensity, sufficient, let's say, so that when the ribbons vibrate, the opening between them varies from a thousandth minimum to three thousandths maximum. The line of light on the film will then vary in width from ½ to 1½ thousandths. Then when it is at the minimum width the exposure received by a point on the film as it passes will be ½ divided by 18,000, that is, 1/36,000 second. At maximum width, the exposure will be 1½ divided by 18,000, that is, 1/12,000 second, or three times as much. With the exposure varying from point to point like this, the density will also vary, and hence we will obtain what we require for a photographic sound record, namely, density variations corresponding in number to the sound frequency and in amount or contrast to the loudness.

More money can be wasted in "saving" money by refusal of theatre managers to provide required projection equipment repairs than in any other one way known.

RCA Photophone Recording

RCA PHOTOPHONE, INC., records sound upon standard thirty-five (35) millimeter wide film, the actual sound record, or "sound track," occupying a space of .070 of an inch wide. The sound track is located upon the right-hand side of the film as it is threaded into the motion picture projector and its sound attachment.

What is known technically as the "variable area" method of recording is employed. The record consists of a series of more or less sharply angled and more or less wide opaque peaks, the same extending across or partly across the width of the sound track, their bases next the sprocket holes. Between each pair of opaque peaks there is, of course, a transparent peak, the base of which lies in the opposite direction. This is clearly shown in Fig. 385, which is a photograph of the sound track, many times enlarged.

The edges of the "peaks" represent the vibration of the microphone diaphragm, hence the sound waves which set the diaphragm into motion, but in the reproduction the sound is really the result of the variations in light intensity set up by the passage of the line of light from the slit through the transparent "peaks" in the sound track.

It is a very difficult matter to put an intelligent explanation of the effect of this sound track upon the light beam into words, but I will try. Examining Fig. 385, it is not difficult to understand that if a thin line of light

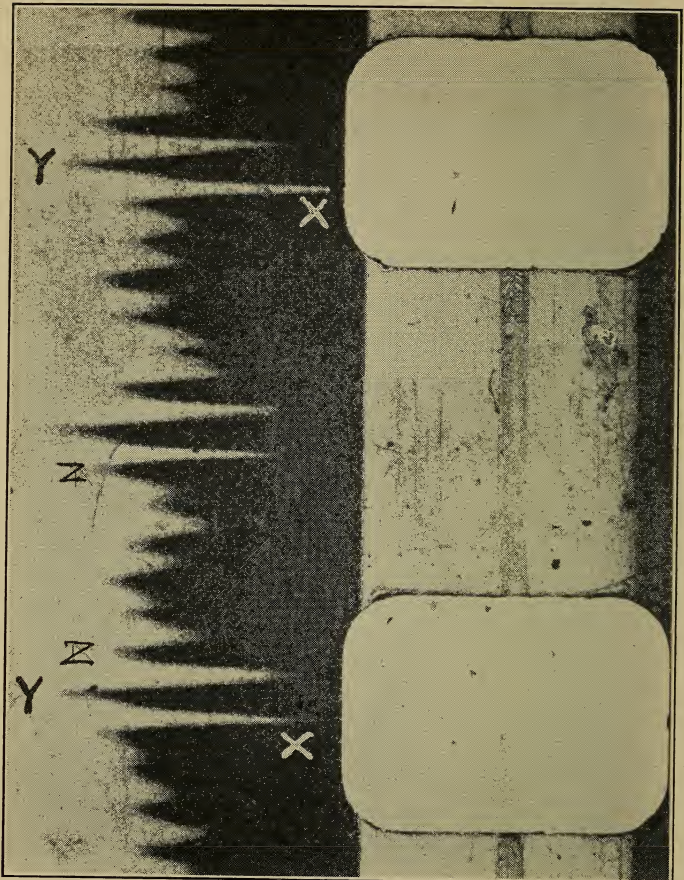

Figure 385.

RCA Photofilm sound track enlarged approximately twenty-five times. It will be noted that certain of the peaks extend much further out than others, indicating a high degree of modulation for the frequencies they represent. The frequency of the sound which the record represents at any given point, and the frequency of the sound which will be reproduced, is indicated by the number of peaks per unit length of sound track. The volume is represented by the height of the peaks, or their width, rather, across the track.

be projected through it, and the section of sound track be moved through that line of light at a high rate of speed—ninety feet per minute, in fact—the black peaks being perfectly opaque, the amount of light passing through the sound track would be varied constantly, and in exact proportion to the height and width of the opaque, or if you prefer it, of the transparent peaks.

For example, at X and X, Fig. 385, during the time the transparent peaks are passing through the line of light it, the light, will reach the photo-electric cell at about seven-eighths of its full possible strength, hence the photo-electric cell will send out, during that infinitesimal fraction of a second, almost its full power in E.M.F.

On the other hand, at YY for the minute fraction of a second, about seven-eighths of the light will be shut off, and the photo-electric cell will only send out a very weak electrical impulse. From Z to Z many less pronounced modulations of light will occur, each of which will, of course, affect the electrical impulses sent out by the photo-electric cell, and therefore the amount of vibration set up in the loud speaker reproducer diaphragms.

Comparing Fig. 385 with Fig. 383, which latter illustrates the variable density method of recording and reproduction, it will be seen that the difference is so very marked that there is indeed but slight resemblance. However, the effect, in sound reproduction, taken as a whole, is not very different.

The variable area method of sound recording, as used by RCA Photophone, differs from other methods in that it employs two separate films for making the final record of sound and motion—one for the sound and one for the motion pictures.

In recording the motion pictures a standard motion picture camera is employed, differing in no detail from the cameras used for silent pictures. In making the sound record a device called the "sound recorder" is used, which is in no way connected with the camera, save only that both are driven at precisely the same speed, by means which will be hereinafter explained. The sound recorder uses not only a different film, but a different kind of film as well, it and the motion picture negative being afterward combined into one positive in the printing machine, as will be hereinafter set forth.

I have said a different kind of film is used for sound recording. That is because, while the usual negative is of course used in the camera, it was found that for sound recording a positive film gave best results. It therefore is used. I understand the positive film produces a record less marred by extraneous noises, commonly termed "ground noise" or "surface noise."

Under the conditions described it is obviously imperative that both the motion picture camera and the sound recorder be driven at precisely the same speed—the speed which will cause each to pass exactly ninety feet of film per minute. In the very nature of things no variation in the speed between the sound recorder and the camera can be tolerated.

Absolute duplication of speed in both is secured in a very simple manner. As you doubtless all know, if two synchronous motors, which we will assume to be sixty cycle motors, be connected to the same 60 cycle power supply, they must and will run at exactly the same speed. It is electrically impossible for them to get "out of step" with each other. Any variation in speed caused by variation in voltage, frequency or load will affect both exactly alike. And that is how it is done.

Two synchronous motors are employed, one to drive or pull the camera, and one the sound recorder. Each motor is built to operate on the same current frequency, and is geared to move exactly ninety feet of film past the aperture each minute. The plan is simple and highly effective.

THE SOUND RECORDER.—The sound recorder consists of three main parts, namely an oscillograph galvanometer, an optical system and a motor-driven mechanism to move the film past the recording light beam. There are of course the usual light-tight magazines, sprockets, etcetera, plus a rather heavy flywheel to insure perfect constancy of movement.

The recording of sound is accomplished substantially as follows: The sound waves strike the microphone diaphram, and in so doing effect a marvelously exact transformation of the sound wave into electrical impulses or current. These impulses or this current is weak past understanding by any except the trained mind of an electrical engineer.

This current is passed through two stages of amplification. The process of amplification is described in full detail on pages 1025 to 1035, to which I advise you to turn before continuing.

After the two-stage amplification above described, the current is sent to a mixing panel, located upon the main recorder amplifier, which same is for the purpose of combining the circuits from two or more microphones, if more than one is used.

From the mixing panel the current passes directly to the main amplifier panel and passes directly into the first stage of amplification of the main amplifier, and thence through four successive stages of amplification before being finally sent forward to the apparatus it is to operate.

Some idea of the weakness of the microphone current may be had when I tell you that before reaching the point of use at the loud speakers it has been amplified at least one hundred million times. No one seems certain as to the exact figure. Some engineers have placed it as high as half a billion times, so I think 100,000,000, huge as it seems, is probably not excessive.

From its last stage of amplification the current is sent directly to the sound recorder oscillograph galvanometer, which it is to operate, and in so doing record the sound upon the film in the manner I shall now describe.

HOW THE RECORD IS MADE.—The oscillograph galvanometer consists of a molybdenum loop, through which the amplified microphone current circulates. This loop is suspended in a magnetic field, and to it a small mirror is cemented.

The light for recording the sound upon the film sound track is supplied by a small incandescent bulb, very similar in external appearance to those used in automobile headlights. It, however, has a coiled filament forming a straight line. This filament is suspended or held in horizontal position. Light from it is passed through a small condenser lens and focused upon the before-named mirror, from which it is reflected through another condensing lens and concentrated upon a slit formed by two microscopically adjusted knife edges, so that an opening .002 of an inch high by .280 of an inch wide is formed.

The light from the lamp being concentrated upon this opening, it of course follows that a beam of the above dimensions will emerge upon the opposite side. This beam is then passed through a tiny objective lens which optically still further reduces its dimensions to .0005 of an inch high by .070 of an inch wide when it finally reaches the sound track of the film.

When the oscillatory galvanometer is at rest—no current reaching it from the microphone—the light beam covers only half the width of the sound track. When the microphone current passes through the molybdenum loop, however, it, the loop, starts to vibrate, and of course the mirror, being cemented to it, vibrates with it, in synchronism with the frequency of the sound waves, with the result that the light beam is moved sidewise across the film sound track, the action "exposing" a portion of it to the light thereof, which exposed portion constitutes the sound record. It is shown you in Fig. 385.

It will be understood that since the film moves at the rate of exactly ninety feet per minute, which is steady and unvaried, if the mirror vibrates rapidly the base of the "peaks" (Fig. 385) will not be so broad as will they if the vibration be more slow. Also if the vibration be slight, the height, or more properly speaking, the width, since they lay in horizontal position, will not be so great as they will be if the vibration of the mirror be heavier.

The width of the "peaks" represents volume. The higher or wider the peak, the greater the volume of sound it represents. The thickness of the "peaks" represents the sound frequency. The thinner the peak the higher the frequency it represents; conversely the thicker the "peak" the lower the frequency.

That is very simple when we come to consider it. Since the film moves at steady speed, if the sound frequency be such that the mirror is vibrated with great rapidity, naturally there is less time per vibration, hence the film will move a less distance during its continuance; the "peak" will therefore be of less depth—less broad at its base, than would be the case did the frequency be lower, hence the film able to move a greater distance during the continuance of each vibration.

And since the amount of movement of the mirror per vibration is controlled by the volume of sound (the greater the volume the greater the movement), it follows that as volume is increased, the height of the "peaks" is also increased because the light line will be moved or swung farther across the sound track.

There, I think that is as clear as it is possible to paint the thing with words.

The method of establishing perfect register in synchronism as between the motion picture and sound film in the printer is to place registering marks on each film.

This may be done in any one of several ways, one of which is to have a person stand before the camera both before and after each shot and bring two sticks together with a sharp impact. Thus each film has the imprint, one in the form of a photograph; the other in sound.

Another method employs magnetically operated marking lights placed in both the camera and sound recorder. The camera has a small mazda lamp, so placed that when a shutter is operated a thin line of light strikes the edge of the film outside the sprocket holes. Upon development a thin black line appears. A similar shutter controlled light is placed in the sound recorder. The shutters of both lamps are operated by one push button when the mechanisms are at rest, so that the "exposure" is absolutely simultaneous. It then remains only to bring the lines thus made upon both films together in the printer, and perfect synchronism is established.

I believe that supplies a sufficiently complete description of RCA sound recording to give you at least a fair idea of how it is done and just what the impressions upon the sound track really stand for.

The distance between picture and sound record is the same as in other systems, namely fourteen and one-half (14½) inches.

Do you oil the projector mechanism occasionally, or give the mechanism and films an oil bath?

Sound Reproduction

The Care Which Must Accompany the Handling and Splicing of Sound Film

HAVING briefly described the methods of recording sound, let us now take up the real purpose of this work and examine into the method or methods of again "picking it up," amplifying it and delivering it to theater audiences, which same constitutes the work of the motion picture-sound projectionist, insofar as he has to do with sound.

CLEANLINESS ESSENTIAL TO SUCCESS.—Cleanliness is essential to the best results in silent picture projection. It is infinitely more so in sound projection. Dirt on the film means scratches on its surface. Scratches in the silent picture means rain, which may be reduced in visibility by cleaning the film. Scratches on film which carries the sound record means "rain," but that is not all for it also means damage to the sound band, and damage to that means irreparable injury to the sound itself. Once the sound band is injured by scratches, the damage cannot be repaired. It therefore follows that dust and dirt and sound are mortal enemies.

Dirty oily hands should not be permitted to come into contact with sound film. A dirty fingerprint on a sound band will be projected to the horns or loud speakers in some form of a blur in the sound. One or two such marks in a reel of film might be negligible. They might even pass entirely unnoticed, but in the process of rewinding, repairing, et cetera, films are handled a great deal, and if the men so handling them have dirty, oily hands, the results will soon become very apparent in the reproduced sound.

Moral: Sound projectionists should make it their invariable practice to remove any oil or dirt from their hands before handling sound films. Of course it is true that that rule should be adhered to by all projectionists, silent or sound, but the point is that with sound it becomes imperative.

Dust in the air in a projection room also is very, very bad in any event, but where the films carry a sound record it should be kept to the absolute possible minimum. If there is dust in the air it is inevitable that some of it will be deposited on the films, and that in the process of projection and rewinding—particularly the latter—scratches on the film surface, including the sound band, will result.

Such scratches usually are minute in size, but they nevertheless set up what is called "surface noise," which is a sort of grinding sound when reproduced by the horns.

It is strongly recommended that projection room floors be not swept with a dry broom. Before sweeping, if a broom is used, hold it under a water faucet a moment, or dip it into a pail of water. This will appreciably reduce the resultant dust. **Never leave film exposed while sweeping the projection room floor.**

It is strongly recommended that the management provide a good vacuum cleaner, with suitable attachments, and that at least once each week all parts of the projection room, including walls and ceilings, be gone over thoroughly. In the end it will be a paying proposition, because of the fact that dust in the air joins with the oil and forms a mild grinding paste which wears projector bearings much faster than they would wear were the dust not present. That is not a mere well sounding statement. It is cold **fact.**

A vacuum cleaner also, if provided, may be used for removing accumulations of carbon ash, etc., from the lamphouses, and for sucking or blowing the dust from around the armatures of motors and generators.

INTERCHANGEABILITY OF FILMS AND APPARATUS.—The film sound track has been what amounts to standardized at one-tenth (1/10) of an inch wide. That is to say, so far as is known, all producers of sound film are using that width, and any sound track of that width may be projected upon any make of apparatus built for that sound track width.

For example: Movietone, RCA Photophone, DeForest Phonofilm, Powers Cinephone films, may all be projected with the apparatus of either of the said companies, all of which are at this time being built to accommodate disc record reproduction as well.

CLEANING SOUND FILM.—In cleaning film great care must be exercised not to exert sufficient pressure to scratch the sound track in any degree. Of course the method to be pursued varies with the amount and character of the dirt. You are referred to page 290, Volume 1, concerning the general proposition of film cleaning.

With regard to sound film, particularly the kind which carries the sound in almost microscopically minute lines extending across the sound track (variable density), the problem is to remove the dirt without causing even very small, faint scratch marks. Any scratches at all in such a sound track, no matter how minute, will cause "surface" or "ground" noise at the horns or loud speakers.

Because of the difficulty of removing dirt, particularly oil, without applying sufficient pressure to cause some scratching, I hesitate to advise as to just what method may be best, preferring to suggest that you, knowing the evil effects of scratch marks, use your own good judgment.

I would, however, suggest that when cleaning is attempted, only some very soft material should be used for the pad through which you draw the film, and that the material should be changed frequently, because it will of course collect the dirt in its surface.

I am of the opinion that, because of the difficulties of cleaning without injury to the sound track, the projectionist is justified in refusing to do it at all. Cleaning is a **duty** of the exchange. Their contract with the theatre automatically presumes film in first class condition to project—"first class" according to the class of service the theatre is paying for. **Regardless of the class of service, however, it may be fairly assumed that it is a part of the duty of the exchange to maintain the films in as perfect a state as the class they represent will permit, and while the fact that a theatre takes cheap service may justify mechanical imperfections which cannot be avoided, such as bits removed in making splices, it does not justify the supplying of dirty films, because that imperfection is unnecessary in that it may be removed by the exchange.**

In other words I believe we have both the legal and moral right to assume that the exchange contracts to keep the films supplied, regardless of the class of service, in as good condition as is reasonably possible, and that therefore it is the duty of the exchange to subject its films to a thorough cleaning as often as may be necessary to enable their projection with good results, both in pictures and sound.

SPLICING SOUND FILM.—NOTE: These instructions apply alike to all kinds of film upon which the sound itself is recorded. It is of course essential to excellence in results that any film, be it silent or sound, be carefully and correctly spliced. It is, however, true that a poorly made splice in sound film is likely to result more harmfully than a poorly made one in silent film. This is because of the fact that there is the same possibility for damage to picture results there is with the silent film, plus the possibility for damage to the sound. It therefore is of very great importance that the projectionist not only know how to make a good, sound film splice, but also that he put that knowledge into practice.

Viewed merely from the standpoint of making a splice —fastening two ends of film together—there is no difference between the silent film and sound film splice. Each should be the same maximum and minimum width. Each is made exactly the same as to mechanical details. Each must be firmly cemented through its length, with ample cement (applied with just one stroke of the brush) to make a strong splice, but without any surplus cement above the amount so required. **You will find the correct process of splicing film described and illustrated on pages 274 to 280, Volume 1.**

SOUND FILM SPLICE.—The procedure for all sound film splicing is the same. The "variable area" and "variable density" sound films splice requires exactly the same procedure. First make a good, strong splice, **using only approved cement** which, when used properly, will neither curl nor stiffen the film. Then a sort of broad-base triangle must be painted upon the sound track, using a black lacquer for the purpose. **Do not use ink** or similar supposed-to-be opaque liquids. They will not do at all. "Zapon Concentrated Black Lacquer, No. 2002-2," made by the Zapon Company, The Canal, Stamford, Connecticut (that address will reach them if your dealer does not carry the lacquer), is recommended by the producers of sound film and equipment for the purpose. It will be well when ordering Zapon to at the same time order some Zapon thinner, No. 20, as Zapon lacquer is very quick drying, hence is volatile and will evaporate rapidly when exposed to the air. It should be kept tightly corked.

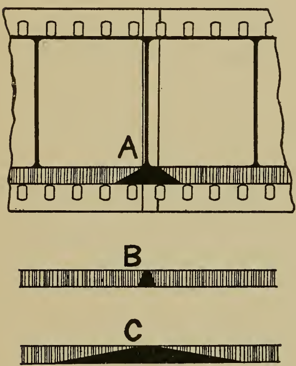

Figure 386.

A—Correct splice, quiet.
B—Too short, will click.
C—Too long, keeps sound off.

The method of placing the triangle is illustrated in Fig. 386. You are again **warned** against attempting to substitute ink, et cetera, for the proper lacquer. It won't work.

If the lacquer be not placed on the splice, or if an improper liquid be used instead of the lacquer, there will be a more or less sharp click as the splice passes the sound aperture. **If the triangle be too long** there will be an appreciable break in the sound; **if too short** there will be a click.

The triangle must have its base at the edge of the sound track next the sprocket holes. The base must be approximately three-eighths (3/8) of an inch long. The apex of the triangle must be at the edge of the splice at the inner edge of the sound track, all as shown in Fig. 386.

If the splice itself be made in accordance with instructions for making splices, pages 274 to 280, Volume 1, and the lacquer be carefully and properly applied, then the splice will pass through without appreciable effect upon the sound.

May I suggest that you locate your lacquer bottle and cement bottle side by side—the handle of the lacquer brush thrust through the cork tightly—so that it will always be convenient, and there will be no temptation to omit the triangle.

IMPORTANT.—In making sound film splices, the projectionist should cut away all damaged or weak film, but absolutely not one unnecessary frame. The break caused by the elimination of frames is even more objectionably noticeable in the sound than it is in the action. If an orchestra, for example, be playing, a singer singing, or a speaker speaking, and several frames of film be cut out, you may well imagine that the effect will be far from good.

Without any thought of irreverence, but to show you what an embarrassing situation might arise because of film elimination, let us suppose our President to be speaking at the dedication of a great storage reservoir dam. He says: "God will bless this work. This dam which will make fertile," etc.

But in the repairing of a break in the film, the words "will bless this work. This," have been cut out. You see what an extremely embarrassing situation would arise.

An extremely unlikely case, you say. True, but it is by no means impossible, nor is it at all unlikely that somewhat less embarrassing situations might be set up, so the projectionist should be very careful in the matter of sound film frames elimination. **Wherever possible the effect set up by speech elimination should be tested before trying it on an audience.**

MORAL.—Cut away no more sound film than you must, and be pretty certain what the effect will be if the splice occur in film carrying speech.

MORAL NO. 2.—Keep your projector in such condition and adjustment that a minimum of strain upon the film will occur in the process of projection, which will of course reduce the film damage to the minimum. See General Instruction No. 9, Page 636, Volume II.

DISC RECORD FILM SPLICES.—There are sixteen frames to each linear foot of film, and Vitaphone, which uses the disc system of recording and reproduction, numbers each foot of film of their productions.

At the starting mark you will find an "0." The sixteenth frame following is numbered 1 and the sixteenth frame after that is numbered 2, and so on throughout the reel. In other words, each sixteenth frame carries a number and these numbers are consecutive from 1, or rather from 0 up, a new sequence beginning with each reel. It then follows that in all Vitaphone films there are fifteen unnumbered frames between each pair of numbered ones, hence the position of each foot of film is indicated, and the exact position of each single frame may be readily located.

Nor is that all, for in addition there is, in all synchronized productions, other locating numbers upon the edge of the film by means of which the scene number of the picture may be determined. These numbers are easily distinguished from the footage numbers just described, because on either side of them appears a dash, thus —134—, whereas the footage numbers have no such marking. Should it occur that the footage and scene numbers come into conflict, the footage number is omitted, though it is nevertheless counted in the sequence. Therefore, should a footage number be missed, one will be found when a total of thirty-one frames have been counted.

You will thus see that it is a simple matter to (a) ascertain whither or no any frames have been cut out by some former projectionist who was obliged to make a splice, and if so exactly how many. If there are only eleven frames between two consecutive footage numbers, then you know that 16 — 11 = five frames have been cut out. (b) Order the exactly right frames to make replacement, if it is necessary or advisable so to do. There are, I repeat, fifteen frames between each set of consecutive numbers. If on one side of a splice the footage number was 287, and there were six frames between it and the splice, and on the other side there was number 288, with two frames between it and the splice, then you know that frames 294 to 301, inclusive, have been cut out—seven frames in all.

To maintain synchronism you may insert seven frames of blank (opaque) film such as is used for leaders and trailers, but be certain you have exactly the right length. The best way is to lay out a space on the edge of the work bench or rewind table, with a suitable mark every three-fourths of an inch. You then, beginning at one end, place a number between each pair of marks, 1, 2, 3, 4, etc. With this lay-out you have only to count the number of frames that have been cut out, lay your blank film with one end at the end of the lay-out—the end marked "1," and cut of the right length, plus the 1/8" necessary for the splice end, and splice it into the print. You thus will have a break in the action and a blank screen for a space of time equal to 1/18th of a second for each frame cut out, but you will have reestablished correct sound synchronism, which is far more important than the black-for-an-instant screen.

Of course you will understand that if the last footage number was, for example, 287 and the next one 289 (except in cases where, as before noted, the footage number is omitted), you will know the break has taken out one footage number, and you must take the correct number of frames between 287 and the next remaining one as your guide for the number of frames missing. In any event your blank film must be equal in length to the missing frames if you wish to reestablish perfect synchronism between action and sound.

Sound Reproduction Apparatus

THE PHOTO-ELECTRIC CELL.—In all systems of sound recording and reproduction in which the sound is photographically impressed upon the sound track of a film, the photo-electric cell plays a most important part. It is this marvelous instrument, the product of man's ingenuity, which receives the light beam emanating from the exciting lamp after it has passed through the film sound track, and transforms the variations in its brilliancy set up by the said sound track back into a duplication of the electrical impulses which controlled the variations of light brilliancy by which the film sound track was originally made.

In Fig. 387 we have a view of this remarkable device, the location of which in the pick-up system of the motion picture projector is indicated by "P. E. cell" in Fig. 405.

The "cell" consists of a glass bulb or "tube" of the form shown, the interior wall of which, all but a circular opening on one side, is coated with a thin deposit of silver electrically connected with a wire which enters the bulb through an air-tight seal. This is the negative wire. In the center of the bulb we see a ring-shaped wire connecting with the positive wire, which also enters the bulb through an air-tight seal.

On the surface of the silver deposit described, is another deposit, the silver really merely serving to form a connection between it and the negative wire. It is composed of a special form of metallic potassium, usually light blue in color. This material is extremely sensitive to the action of light.

The ring-shaped conductor connects, through the positive wire, to the grid of the first amplifier tube. The light-sensitive material deposited on the silver coating connects through it and the negative wire to the filament of the first amplifier tube.

The circuit thus formed is connected to a 100-volt storage battery, so that its voltage is impressed upon the two elements of the photo-electric cell.

However, as matters now stand, since the anode (ring-shaped conductor) and the cathode (light-sensitive material) are separated by considerable distance, there would be no current flow. There must be an added element, and this is supplied by the gas with which the cell is filled. It is a rare gas which when the interior of the cell is in darkness is a very poor conductor of electricity. It is in fact an insulator for any but a very high voltage. It therefore follows that when the cell is dark, no current flows.

When this cell is in place in the slit assembly, however, with proper connections made, and the projector is started so that light from the slit which has passed through the film sound band enters the cell through the opening before mentioned, the light-sensitive material has forced out of it, or throws off minute particles of negatively charged electricity called "electrons," and these particles "ionize" the gas, causing it to become an electrical conductor in exact proportion to the amount of ionization.

Please read that last sentence over again and get the idea fixed in your mind. Remember also that we are

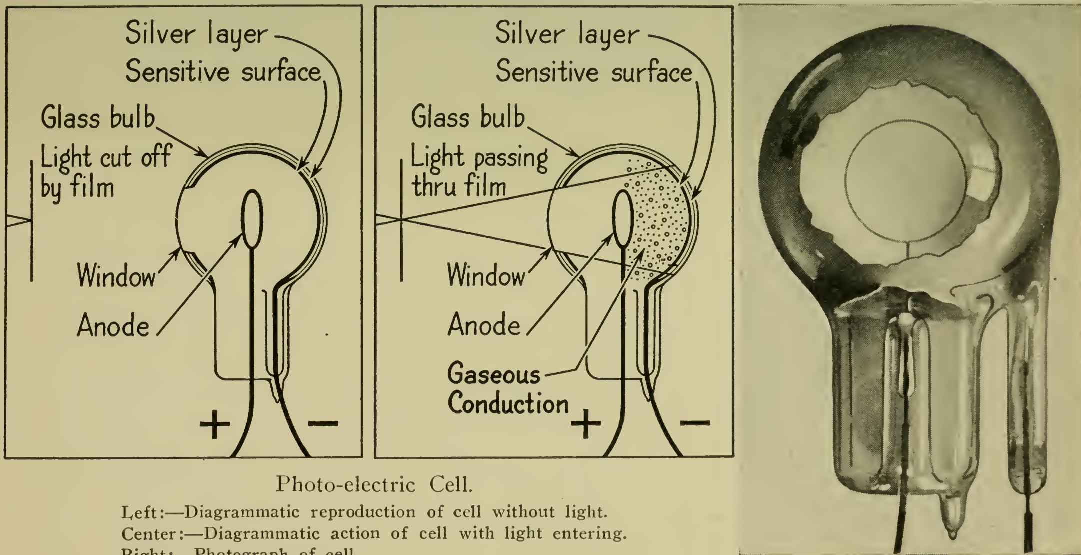

Photo-electric Cell.

Left:—Diagrammatic reproduction of cell without light.
Center:—Diagrammatic action of cell with light entering.
Right:—Photograph of cell.

Figure 387.

dealing with the action of light and electricity, both of which are enormously rapid—more rapid than can be understood or conceived by the untrained mind.

When you have the foregoing clearly fixed in your mind, consider that (a) this light-sensitive material will ionize the gas in exact proportion to the amount of light reaching it at any split fraction of the millionth of a second, and (5) that the amount of light reaching it depends at any split fraction of the millionth of a second upon the density of one one-thousandth of an inch (up and down) of the sound band then passing under the light incident upon it from the slit.

Don't overlook the fact that the current flow between the anode and cathode of the cell will be dependent (voltage constant, remember) upon the ionization, and you have the complete action of the photo-electric cell, which sends forward to the first amplifier in the form of electric current exactly what the microphone sent forward to the actuating impulse governing the variations in intensity or brilliance of the light beam which made the original record upon the film sound track at the camera.

Another interesting thing, and one which it is well that the projectionist understand, is that the impulses sent out by the photo-electric cell are almost inconceivably weak. Indeed, so weak are they that before they can be made to operate the horns or loud speakers, acceptably, they must be built up by the amplifiers approximately one hundred million (100,000,000) times. The projectionist will understand from this that he is handling very delicate forces and apparatus which must function with high efficiency if maximum results are to be attained. Naturally a force so enormously weak that it must be amplified 100,000,000 times before it will reproduce sounds at acceptable volume would be affected by a very small thing, hence it is imperative that the various parts of the apparatus you are placed in charge of be handled intelligently, adjusted with fine correctness and kept in a perfect state of repair. That, I believe, should appeal to you as just plain common sense.

THE CONDENSER.—The condenser is used quite liberally in sound reproduction apparatus, and has important bearings upon its action. It therefore is desirable that the projectionist have a good working understanding of its construction and of the principle upon which it depends for its action.

The condenser depends for its action upon the same action which produces what is known as a "tuned circuit" or a "resonant circuit," which same it has been necessary to describe in some detail in connection with the motor control box, page 1127.

Condensers serve the purpose of an electrical check valve. They permit alternating current to pass with relatively small hindrance, but stop all flow of direct current. One purpose of the condenser is to act as a sort of electrical shock absorber.

The condenser is to electric action what the spring is to mechanical action. They meet and absorb electrical shocks just exactly as the springs under your car meet and absorb mechanical shocks. The condenser represents electrical elasticity. Get the foregoing well fixed in mind, and what follows will be the more readily understood.

The mechanical engineer makes use of various types of springs, each of which is suited to certain services. The coil spring is suitable for use under certain conditions. The leaf spring under other conditions. There is the compression, the pneumatic, the tension spring, etc. Each have their purpose in mechanics.

The same thing is true in condenser as applies to electrics. There are various types of condenser, each suited to a particular class of service. As a matter of fact each of the many purposes for which electrical condensers are used may be closely compared with some well known application of elasticity in the mechanical engineering field. As a matter of fact were electrical action visible to the eye, it would be found that the action of the condenser is just as simple and obvious as is the action of the spring, or of a rubber band when stretched and released.

We can observe the action of a rubber band or a spring. We therefore can instantly understand them and their action. The action of the condenser is invisible to the eye, hence is not so readily understood.

A SIMPLE EXPERIMENT.—A very simple experiment will serve to illustrate the matter perfectly. The rubber band I have spoken of has the two fundamental requirements of elasticity, namely: First, when we apply force in opposite directions to its ends, it stretches and if we measure the amount of stretch in inches and the power applied, we will discover that the power necessary to produce any given amount of stretch would be in exact proportion to the amount or length of the stretch —that is to say, within the limits of elasticity of the rubber itself. Secondly, when the pull is released, the band instantly returns to its original length.

These two properties are found in all truly elastic substances or bodies. Electrical condensers have, as will be shown, precisely analogous properties.

A very simple form of electrical condenser, which compares with the rubber band, insofar as concerns simplicity, consists of two metallic plates having a sheet of insulating material between. For example let us assume the metal plates to be two sheets of aluminum one foot square, with a sheet of insulating material between of somewhat greater dimensions, so that the insulating material protrudes, or "sticks out" say one eighth of an inch all the way around. This latter is necessary to prevent the current from jumping across from one plate edge to the other.

We will now connect these plates to the two opposite poles of a storage battery or other source of electrical power. Under this arrangement it may readily be understood that instead of applying pull to the two ends of a rubber band, or pressure to the ends of a coil spring, we have set up a condition of electrical pressure, measured in voltage, the force of which is and must be borne by the insulating material between the plates.

Under this condition the condenser is said to be "charged." The sheet of insulating material is under a state of electrical strain just as truly as would be a coil spring with pressure applied to its ends, or a rubber band with pull applied to its ends. That is simple enough, is it not?

It also is plain that the strain the insulating material is under will be exactly proportional to the voltage applied, exactly as the stretch of the rubber band is proportional to the pull exerted.

When we release our coil spring or rubber band, they snap back to their original state. Similarly if we open a switch, thus breaking the power circuit with which the condenser is connected, and "short" the two plates across the insulating material by means of a wire, the condenser will "discharge" itself and return instantly to its former uncharged condition.

Understand, when we disconnect our condenser from the power supply we do not release the strain. There still remains the "charge" in its plates which corresponds to the pull upon the rubber band, and unless the plates be shorted, that charge and strain will remain an appreciable time, in some types and sizes of condensers several minutes; in others a much less time. The charge will, however, gradually leak away whether or no the plates be shorted. If the condenser be large enough and be charged with say 100 or more volts, there will be a visible spark when the plates are shorted.

RETAINS CHARGE.—I repeat: a condenser will retain its charge, unless the charge be in some manner used up or the plates be shorted, for a length of time depending upon the size and character of the condenser. It will vary from less than a minute to several minutes. The leakage away is gradual.

CAPACITY.—Just as the amount of stretching of a rubber band is proportional to the force applied, so the charge produced or set up in a condenser is exactly proportional to the electrical pressure (voltage) applied.

What is termed the "capacity" of a condenser is the amount of charge it will store for each volt applied, just as the elastic strength of a rubber band may be expressed as or in the number of inches it will stretch per pound of force applied.

If we stretch the rubber too far it will break. If we apply too much pressure (voltage) to a condenser its insulating material will break down in the form of what we term a "puncture."

The simple form of condenser described is seldom met with in actual practice, just as rubber bands are seldom found applied to mechanical practices, except for holding papers together. However, it was from such a simple beginning that the devices now in use were developed.

In the electrical condensers now in use we find the metal plates and the insulating material, but because it is often desirable to secure considerable capacity without using the large amount of space the use of flat plates would entail, we find in their stead their equivalent in sheets of tin foil only about two one-thousandths of an inch thick, with insulation, in the form of paper, of only slightly greater thickness. Both these are cut into long strips and wound into rolls for the sake of compactness. A condenser of considerable capacity may therefore occupy small space, yet it operates just the same as does the flat plate condenser described, and is just as efficient.

THE RUBBER BAND AGAIN.—Returning to our rubber band as the most convenient illustration, let us see just how our condenser works. If we attach a weight to one end of a rubber string, formed by cutting a rubber band in two, of just sufficient weight to stretch it moderately, we shall find that if we give the end we hold a sharp twitch upward and then hold it stationary, the weight will bob up and down and continue to do so at exactly the same rate of movement per minute for some time. We shall also find that, provided we keep time with that movement, it will require only a very slight movement of our hand up and down to maintain that bobbing at the same value. However, if we alter the movement of our hand so that it is out of time with the movement of the weight in any degree, we shall discover that we cannot alter the time of movement of the weight, unless we alter the weight of the weight or the size or elasticity of the rubber band. In other words that particular band and weight will only "bob" at one set speed and no other. Kindly do not ask me why that is so, for I don't know, nor to date has any one been able to tell me in language any ordinary human could possibly understand.

Note.—It's a bit wonderful what terms, language, etc., the engineers can summon to their aid to befuddle we poor humans when (we strongly suspect) they don't understand some matter any too well themselves.

If we substitute the hairspring of our watch for the rubber band and weight we shall have exactly the same thing in another form. That is why the watch keeps time. The hairspring of the watch represents the rubber band; the momentum of the wheel the weight and the mainspring of the watch, gravity and the movement of our hand. Try to get that balance wheel to perform at any other beat without changing something!

Similarly in resonant circuits and tuned circuits (essentially the same thing) and in oscillators, etcetera, condensers are employed as the electrically elastic members of the combination which forms the desired effect of setting up electrical vibration or oscillation at a certain rate or frequency.

VARIABLE CAPACITY.—In radio work, condensers are used which employ the medium of air for insulation between the plates, instead of paper, etc. Altering the relation of the plates of such condensers with relation to each other has the effect of altering the capacity of the condenser. That is why moving the knob attached to your radio condenser or condensers enables you to "tune in" on various stations having different wave length or K. C. frequency. You thus alter the capacity of the condenser by changing the relation of the plates to each other until it will permit the current frequency of the desired station to pass.

That, gentlemen, is about as clear as I feel able to make the action of condensers.

Some may wonder why the name condenser is applied to the instrument described, since there really is nothing "condensed." The answer is that when condensers were first evolved, in the early days of the science of electricity, it was believed the energy used in charging the plates had been in some manner condensed upon their surfaces.

Others may ask if it would not be possible to use condensers to store up power. The answer is no, because a condenser capable of supplying any large amount of power would have to be of literally enormous size and weight. Such an instrument could, of course, be constructed, but due to excessive weight, size and expense, it would be entirely impractical.

What doth it avail if a theatre manager "save" $25 by refusing to have projector repairs made and in so doing lose $2,500 at the box office?

The Vacuum Tube as an Amplifier

WE will now proceed to examine the vacuum tube regarding its action in amplifying the electric impulses coming from the sound pickup apparatus, sending it forward to the horns or loud speakers vastly more powerful than it was before its passage through the tubes.

The amplifying tube does not really amplify the impulses at all, in the true sense. What it does is use the very weak impulses emanating from the pickup at the projector to duplicate those impulses in a very much more powerful electric current. Get that fact fixed clearly in your mind and you will the more readily understand what follows.

When a current-conducting filament is placed in an air-tight receptacle, such as a glass tube, the air exhausted therefrom, and a sufficient current is sent through to heat the filament, it has boiled out of it, or "throws off" negatively charged particles of electricity called electrons, which travel at high velocity and in straight lines.

It is this condition which makes possible the amplification of sound, because, as will hereinafter be explained, means have been found to control the action of the electrons thus thrown off in a vacuum tube, and to, by them, force duplications of the impulses contained in the current coming from the pickup in a current of far greater power.

It might here be remarked that up to this time no acceptable substitute for the vacuum tube amplification has been discovered. The vacuum tube may therefore be said to be pretty nearly the "heart" of sound reproduction equipment, which is the reason it has been selected for first consideration.

In Fig. 388 we have the diagrammatic representation of a glass bulb from which all air has, so nearly as possible, been exhausted, and a fairly perfect vacuum thus established, and, since the tube is sealed air tight, it is maintained. The connections of such a tube in an amplifying circuit also are indicated.

In this tube filament F connects to battery A, as shown. Battery A is a twelve (12) volt storage battery. The tube also contains grid G and Plate P, connected as indicated.

NOTE.—It will of course be understood that in actual practice the wires do not connect direct as shown, but through various items of equipment serving various purposes. For the purposes of simplified explanation of vacuum tube action, however, the diagram serves very well, and just now we are concerned only with the action of a vacuum tube when used as an amplifier.

Examining Fig. 388, if we send current from battery A through filament F, the filament will of course become heated, in which state it will throw off electrons, as already set forth, each of which is a tiny particle of negatively charged electricity, or electric energy, the action of which will be governed by the well known electric law that positive attracts negative and repels positive.

In Fig. 388 in the batteries the long lines represent

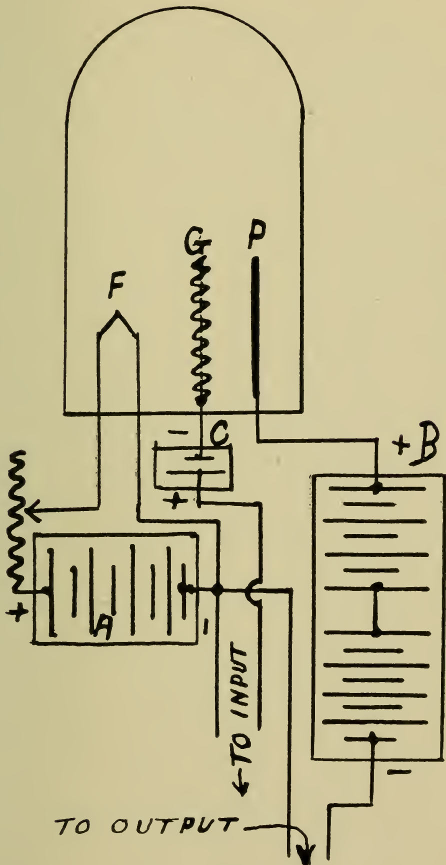

Figure 388.

positive plates, the shorter lines negative plates, so that by examining them you may know which end of the battery is the positive and which the negative terminal.

Plate P is, as you will see by examining the diagram, positively charged by battery B. We then have plate P positively and filament F negatively charged. Grid G also is negatively charged and it is this condition which makes sound amplification possible.

Above all things, in considering such matters remember that you are dealing with action inconceivably rapid —rapid utterly beyond the possibility of human comprehension, except by those trained to the consideration of such things. An electric impulse will travel many thousands of miles in one second of time. Electric changes occur with tremendous rapidity; with a speed far, far in excess of any possible variation in sound. Get that fact fixed clearly in your mind and you will have gone far toward comprehension of what follows.

Returning to our diagram, the three parts within the tube are called "elements," or "electrodes." Usually the latter term is used by engineers. The parts and the glass container (bulb) shown in Fig. 388 constitute a complete audion, or sound amplifying tube. It is that because by means of the combination thus effected the action of the electrons may be controlled, made to work for us and to do our will.

An ordinary electric light globe filament throws off electrons the same as does our sound amplifying tube, but there is no means provided for their control, hence the globe is valuable only for its light producing power.

As you will note by examining Fig. 388, a positive potential with respect to filament F is applied to plate P by battery B. Moreover, grid G is negatively charged or "biased" as the engineer terms it, with respect to filament F by battery C.

Grid G is really the element which controls the action of the electrons and in so doing unlocks the door for sound amplification. The action is as follows: Filament F is heated by current from the A battery, as shown. This causes electrons to be "boiled out" or thrown off, as already described. These electrons from the filament bear a negative charge, hence have an affinity for positively charged Plate P, which of course attracts them, and we thus have a current flow established between Filament F and Plate P, but it is uncontrolled, hence of no practical value in sound amplification. The number or percentage of the electrons thus attracted to Plate P will be dependent upon the strength of the potential, up to the point where all that are liberated from Filament F are attracted.

And we now arrive at the crux of the whole matter. Grid G, interposed between Filament F and Plate P, is negatively charged by the "C" battery.

The flow of negatively charged electrons is from Filament F, toward positively charged Plate P, and since Grid G is negatively charged, and negative repels negative, it acts as a sort of electrical valve, which opens and closes with every slightest alteration in applied voltage, to permit of more or less electrons from Filament F to Plate P. Don't overlook the vital fact that the voltage of Grid G is controlled in its variations by the current emanating from the photo-electric cell, which latter fact is explained as follows: The E M F supplied by Battery C to the grid is of course steady, but the current coming from the P E cell over the input circuit is variable, or vibratory, which has the effect of reproducing those variations or vibrations in the grid voltage.

You will now understand that the flow of electrons from F to P will be in exact proportion to the rise and fall in the negative potential of the grid, and that this rise and fall is controlled by what comes from the photo-electric cell, hence since what comes from the P E cell is an exact electrical reproduction of what the light beam has picked up from the film, it follows that the flow of electrons will be in exact proportion to the sound modulations the P E cell current represents. That may sound a bit complicated, but study it a bit. Once you get the idea the action is clear.

And now we arrive at the crux of this whole matter. The action of the grid requires the application of an extremely small amount of power. The current coming from the P E cell is extremely weak, but it nevertheless is ample to operate not only one but several grids.

On the other hand, we may apply a relatively very large amount of power to the plate, and since the flow of electrons from F to P through G in Fig. 387 serves to reproduce in this larger power every fluctuation of or modulation in the current coming from the P E cell because of the rise and fall in grid voltage it sets up, we are **thus enabled to use a very weak power to set up an exact duplication of itself in a very much greater power** and that is what constitutes amplification.

The hand of a locomotive engineer is enormously weak as compared with the power of the engine, but nevertheless that weak hand is able to control the action of that great engine and its heavily laden train of cars. The principle is essentially the same. As a matter of fact, over in Europe they call amplifying tubes "valves" or "electron relays."

We then see that it is only necessary to apply, by means of the "input," Fig. 388, a weak current to take from the plate, through the output circuit, the relatively powerful current necessary to operate the horns.

In practice, however, more current than one stage of amplification can produce is required for theatre horn or loud speaker operation. Therefore several amplifying tubes are used, connected in series. In the last stage of amplification before going to the horns, two tubes in parallel are used.

Sound is a vibration of the air, of course, and it is worth while remarking here that the currents which the vacuum tube has to deal with are also vibratory, which is natural, since they represent the sounds that are being reproduced. So that although we have a steady negative voltage applied to the grid by the "C" battery, the current coming from the input circuit is vibratory, and this, of course, has the effect of causing the grid voltage to be of a fluctuating character. However, the action is as already described—the plate turns out a similar but magnified fluctuating current, and so the vibratory effect goes on to the sound reproducers.

That, roughly, is how sound amplification is accomplished by vacuum tubes, either in your projection apparatus or in your radio tube. The modulations of sound which cause a voice to be reproduced are in either the film itself, or in the record, in case the record method is used.

Do you boast of your ability to install an intermittent sprocket, or of your ability to get 100 per cent results from the films and equipment supplied you? One is the job of a repair man; the other, the job of a projectionist.

The Vacuum Tube as a Rectifier

IN the preceding chapter of this work, you are told, in detail, in just what manner a vacuum tube is made to amplify current. I shall now proceed to explain how the same tube, or a similar one without a grid, may be used to rectify current, changing A. C. into D. C.

NOTE.—While an amplifying tube may be used as a rectifier, it is not advisable to so use it, because (a) the grid may interfere unless connected with the plate, as explained further along, and (b) a tube once used as a rectifier will no longer function well as an amplifier.

In the chapter which deals with the vacuum tube as an amplifier, it was explained that electric current may be considered as a stream of negatively charged "particles" of electricity, called "electrons," flowing from negative to positive in a vacuum tube, or along wires in an electric circuit.

If the current be D. C. this stream moves along continuously and steadily in one direction, but if the current be alternating, then the electrons chase back and forth around the circuit alternately in opposite directions.

The majority of commercial power and lighting systems operate with A. C., which reverses its direction sixty times per each second of time. That is to say, it flows in one direction for 1/120 of a second, which movement is called a "half wave," or "half cycle." It then flows in the opposite direction for an equal period of time. The two complete movements consume 1/60 of a second and constitute a full wave or "cycle."

I am aware of the fact that most of you knew all that long ago, but this book is for the novice as well as for the man of electrical knowledge and experience. Remember there was a time, and not so very long ago, either, when you and I did not understand such matters at all well. It is very important that the student have a clear understanding and comprehension of them because unless he does he will find himself unable to understand what follows.

The reason a full wave action is called a cycle is because of the fact that during the period (1/60 of a second) the current has traveled its full course once in each direction, and is, in a way of speaking, back where it started from. It therefore has completed one full cycle of action. The terms often heard and seen in print: "sixty cycle current," or a "frequency of sixty cycles," or "sixty cycle frequency" all mean exactly the same thing, and that thing is what we have just described.

We have already seen, page 1029, that in a vacuum tube the electrons flow from the negatively charged hot filament to the positively charged plate. We know that none would flow in the other direction for two reasons, namely: first, the cold plate would not produce electrons, and, second, the electrons are always negative, and since the filament is negative and the plate positive, and negative repels negative but is attracted by positive, the flow could only be from filament to plate. That is the key to vacuum tube action, either in amplifying or rectifying.

In Fig. 389 we see the diagrammatic representation of a vacuum tube, with a battery to heat its filament. Also one lead of a 110-volt 60-cycle A. C. power circuit connecting to the same filament. The other power lead connects, through the load, to the plate. Each lead of the A. C. circuit will of course be alternately positive and negative as the current reverses.

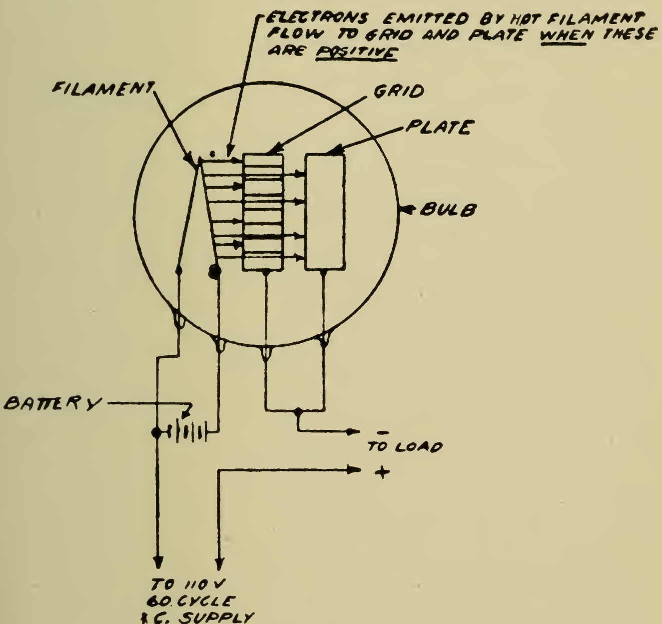

Figure 389.

There is a grid in the tube here shown, it being really an amplifying tube, but you will observe that the grid and plate are joined, and the A. C. lead connected to both. It is not necessary that there be any grid at all in a rectifying tube, but if there is one it must be thus connected, or it may accumulate a charge of its own account, in which event it would interfere with the flow of electrons. However, if there be a grid and it and the plate connected as shown, then it may be an advantage by adding to the effective area of the plate. At any rate, it will do no harm.

NOTE.—I again warn you, do **not** attempt to use a tube as an amplifier which has been used as a rectifier.

Bearing in mind what has been said, it may be readily understood that during the half of a wave or cycle electrons would flow freely from the hot negative filament to the negatively charged plate, but during the succeeding half wave, the plate being negative and the filament being negatively charged by the battery which heats it, none could flow, and we therefore would have only half waves flowing to the load, which of course would all flow in the same direction.

It may be a bit hard for some of you to grasp the meaning of the connection shown in Fig. 389, but study it. The A. C. circuit is actually broken, except for the action in the tube itself. In other words the only current which can flow through it is the electron flow between the filament and plate. The current flow which heats the filament is D. C., of course, and does nothing but heat the filament, because it has no circuit connection elsewhere. The fact that the A. C. lead connects to it on one side affects neither it nor its action, because its other "side" does not connect. However, the A. C. has a complete circuit through the flow of electrons between filament and plate and the load back to its positive terminal.

I hope I have made this clear. It is no easy task to put such matters into understandable form. I can myself well remember the struggle I had trying to dope out the electrical action from drawings and "explanations" made by engineers when I was trying to get some sort of understanding of electrical mysteries. The engineers meant well, but failed to understand how puzzling some things might be to the novice, but seem as clear to them as the country air.

This far we have examined the principle of vacuum tube rectification only, and that principle would not have much value as an amplifier "B" battery eliminator, for the following reasons:

(a) A battery is necessary to heat its filament.

(b) The rectified current is of the same voltage as the supply, which usually is 110, and in amplifier operation higher voltages usually are necessary or desirable.

(c) We only "get" half of each wave, hence the current comes in jerks, with gaps between each half wave. It would be what is called a strongly pulsating current. Not only that, but also only half the power is available.

We therefore must go further, and Fig. 390 illustrates, in diagrammatic form, the way those drawbacks may be avoided. At the left side of the diagram are leads connecting to the 110-volt A. C. supply. This current does not go direct to the rectifier tubes, but to the two transformers, T1 and T2 (transformers are used to change the voltage of A. C. power; as shown in the diagrams they have two windings, the primary winding, connected to the supply leads, and the secondary, connected to the circuit using the power). T1 delivers a low voltage for lighting the filaments of the vacuum tubes V1 and

V2, thus eliminating the need for a battery. T2 delivers a high voltage to the plates and grids of the tubes, which overcomes the second difficulty mentioned. From the middle of the secondary windings of T1 and T2 a pair of wires carries the rectified current via the filter to the load, consisting of the amplifier plate circuit.

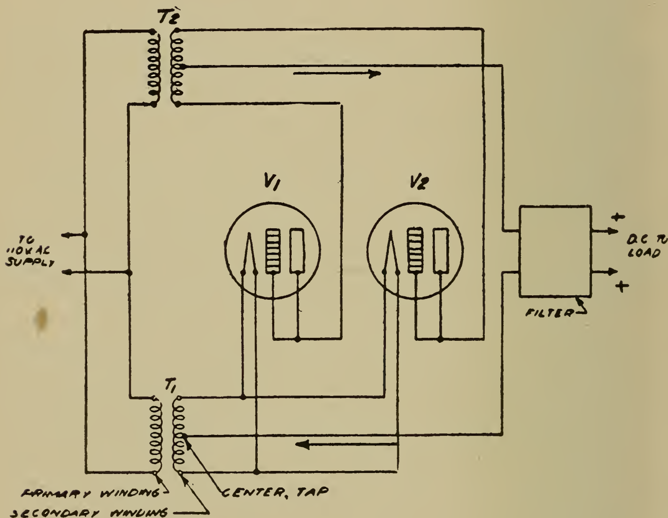

Figure 390.

To explain the action of this arrangement, notice that the plates of V1 and V2 are connected to *opposite* ends of the secondary winding of T2. If there is a voltage across this winding, the two plates will therefore be *opposite* in polarity. Now imagine an instant when the A. C. voltage in the secondary winding of T2 is making the plate of, say, V1 positive. Then starting from the filament of V1, current will flow to the plate and grid, then to the lower end of the secondary winding of T2, out through the center tap to the filter and external circuit, back to the center tap on the secondary of T1, and through the two halves of the secondary winding back to the filament of V1. Of course, no current will flow through V2. This state of affairs will continue until the end of that half wave; then on the next half

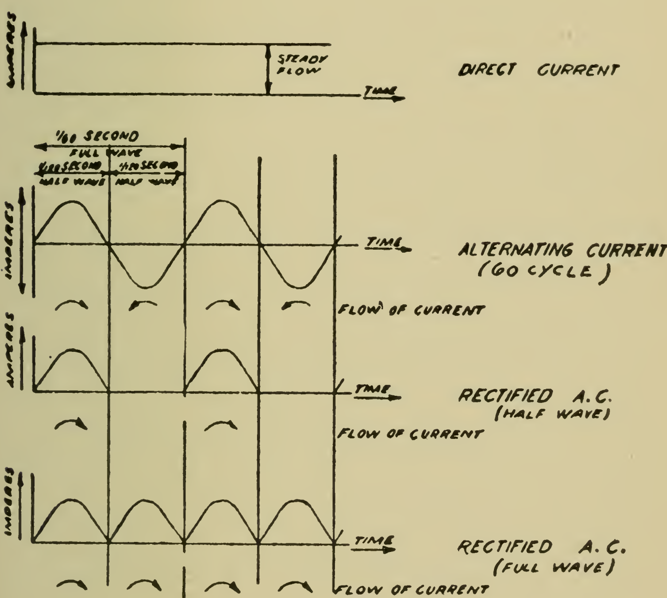

Figure 391.
Diagram of alternating current waves.

wave, things will be reversed. Whereas the lower end of the secondary winding was positive previously, now the end that is postive will be the upper end, connected to V2, and current will pass through this tube and nothing through V1. But, just the same, the current from the plate of V2 will go out through the center tap of T2 as it did before; and we see that our rectifier is now using both halves of the A. C. wave.

We must be careful to point out that the process just described does not produce true D. C., but a hybrid current called "rectified A. C.," Fig. 391, which resembles D. C. in that it always flows in one direction, but differs from D. C. in that it is not steady. Every half cycle it drops to zero, then shoots up to a maximum, drops to zero again and so on. In other words, it is a pulsating current. The reason for this is that, as shown in the diagram, Fig. 391, the A. C. does not *suddenly* change its direction at the end of each wave, but drops down gradually to zero and then increases again in the opposite direction to the maximum for the next half wave, just as when you are driving your car forwards you cannot start to go backwards in an instant; you must slow down, stop, and then build up reverse speed. For some purposes, such as charging batteries, there is no objection to rectified A. C. with its ups and downs—it may even be sufficient to use half wave rectification, thereby eliminating the second tube. However, for amplifier plate supply we must have true D. C., even more free from irregularities than the current obtained from the mains in most D. C. districts. Otherwise the output of the amplifier would be rendered useless by reason of the loud hum accompanying it.

To obtain from our tubes the kind of current we want for amplifier work, one further step is necessary. The rectified A. C. must be made smooth and steady by passing it through the filter previously mentioned, which is a combination of choke coils and condensers that may be described as an electrical shock absorber. In your car the road bumps are prevented from reaching you by the elasticity of the tires, springs and cushions, combined with the weight of the car itself. In exactly the same way condensers, acting as electrical springs, and choke coils, acting as electrical inertia, remove the irregularities from rectified A. C. and make it into true D. C., any small ripples that may remain being either so weak or else so low or so high in frequency that they are inaudible in the amplifier output.

There are some men who know it all. They cannot learn any more. The cemeteries are full of them.

To tackle a problem in projection blindly is a waste of effort. You will have trouble opening an oyster with an axe. If you study its shell, you can open it easily with a small knife.

Amplifiers and Their Care

NOTE.—This applies to amplifiers of all equipment dealt with in this book.

IT is of course essential to the production of good results that the amplifiers and the amplifying system as a whole function perfectly, which means that the amplifiers must be cared for and kept in as nearly perfect condition as possible.

Under the title "The Vacuum Tube as an Amplifier" I have tried to give you an understanding of the fundamentals necessary to the intelligent consideration of such troubles as may arise in connection with amplifiers. When we understand in just what manner the vital parts of an equipment functions, we are in position to deal intelligently with troubles which may arise in connection with it.

The tubes, while they give a relatively very small amount of trouble, may, and very likely will, eventually give some. It is your job to be able to recognize those troubles or their symptoms, rather, and thus be able to deal with them before they become acute.

The life of an amplifying tube is not reckoned in days. It is figured in hours of actual service, which will of course vary somewhat with individual tubes, though it is not supposed to, but will vary very greatly in accordance with the amount of abuse to which it is subjected.

The filament of an amplifying tube is heated by current from a storage battery of approximately twelve volts pressure. **It is extremely important** that the filament current be maintained at **exactly** the value indicated in the instruction book supplied by the installation engineers. If the filament current be too high it will very greatly shorten the life of the tube without any corresponding benefit. If the current be too low, then, while the tube itself will take no damage, the sound volume will be low; also the quality of sound may and probably will suffer.

The reason why the life of the tube is shortened by too much current is that the too-hot filament throws off electrons at an excessive rate, hence the oxide filament coating, which supplies most of the electrons, rapidly becomes exhausted. This of course reduces the flow of electrons, and finally brings about the destruction of the filament.

VACUUM TUBE FAILURE SIGN.—When an amplifying tube filament fails, it usually first weakens at one spot. This spot will glow much more brightly than the rest of the filament. **Replace the tube with a new one immediately upon seeing this warning sign.** If you neglect to do this, it is not at all unlikely the filament will fail right in the middle of a sound reel, which will be very embarrassing.

I again warn you to keep the amplifying tube filament at exactly the voltage indicated in your equipment instruction book.

Noisy tubes will occasionally be found. The noise is caused by the filament throwing off electrons at an irregular rate. It is only occasionally that a noisy tube will be encountered. Such tubes rarely give trouble anywhere except in the first stage of amplification, where the high degree of sensitivity required makes a noiseless tube essential.

If you suspect a noisy tube, set the fader at zero. If there then is noise, you have good grounds for suspecting a tube, and should remove the first stage tube from the first amplifier, exchanging it for a tube from elsewhere, or inserting a spare tube. If this stops the noise, that of course settles the matter. If it does not, then you must look elsewhere for the seat of the trouble.

Batteries supplying current to the amplifiers must be kept in perfect condition. See page 1083. Loose connections or accumulations of dirt or acid on the battery tops may be the cause of fluctuations of current, and since this current is delivered to the amplifier, trouble will follow. Such fluctuations are amplified, and are reproduced by the horns or loud speakers, just as are the sound current fluctuations picked up from the projector pick-up system. They make themselves manifest by "frying" and crackling sounds.

WARNING.—As has been set forth under "Care of Batteries," page 1083, you must in no event use batteries for sound reproduction within from twenty minutes to half an hour after charging has been completed. During that period the electrolyte continues to give off gas, and noise at the horns will result if they are used.

INSPECT "C" BATTERIES.—The newest types of amplifiers have no "C" batteries, the "C" voltage being obtained from the potential drop across a resistance in the plate circuit. The amplifiers used previous to these, however, have "C" batteries and will not function properly unless the "C" battery voltage, which keeps the tube grid negative and, in a way, is the key to sound amplification, be maintained at its proper value. This battery should be inspected once every thirty days, say on the first day of every month, and the voltage tested. If you have Movietone or Vitaphone, or both, then on the front of the battery box you will find a set of small metal contact studs with which connection may be made with a low reading voltometer.

Your operating instruction book will give you the proper voltages between each pair of these contact studs on each type of amplifier. Plate current greater than those specified in your operating instruction book are an indication that the grid voltage is not high enough, which, if the "C" battery is in good condition, may be due to their making poor connection with the grid circuit. This fault may be remedied by scraping the contact lightly with a knife blade, or rubbing with sand or emery paper or cloth. This refers to the battery springs and contact springs at the bottom of the battery box. It also may be advisable to bend the battery springs to insure a firmer contact pressure.

It also is possible that there will not be good contact at the base of the vacuum tube, which would, of course, result in lowering the grid voltage, or affect the plate or filament current. **In such cases do not use an abrasive to clean the contact; also do not scrape the contact with a knife blade. Clean the contact with a rubber eraser.** If you scrape them, or use an abrasive, the contact will become pitted, and eventually be worse than it was before you cleaned it.

WARNING.—Do not hold your voltometer in contact with the "C" battery longer than is necessary. It draws current and helps to exhaust the battery.

RECTIFIER TUBES.—Where a portion of the amplifier power comes from rectified A. C. it is, of course, essential that the rectifier tubes be in good condition. What has been said concerning the care of amplifier tubes applies equally to rectifier tubes. The filament current value must not exceed that specified in your operating instruction book, nor should it be less than that value. When tubes begin to give indication of deterioration, they should be promptly replaced.

In Western Electric installations two rectifier tubes will be found. This is to enable the using of both halves of the A. C. wave.

IMPORTANT CAUTION.—The amplifier tubes and photo-electric cell at the motion picture projector in Western Electric installations are suspended in a spring cradle. This is for the purpose of absorbing the vibrations of the projector mechanism. **It is very important** to see to it that this cradle swings free of everything. Should it touch any part of the projector, mechanical vibrations will be picked up and carried forward and heard in the horns.

AMPLIFICATION DIAL SWITCH.—The amount of amplification produced in Western Electric installations is controlled by means of the dial switch of the first amplifier of the set on the rack. **This switch will be set by the installation engineers, and that setting should not be altered except upon instructions issued by, or with the approval of the service engineer.**

FILAMENTS IN SERIES.—In some instances two or more tubes are operated with their filaments in series. In such cases the failure of a filament in one of the tubes will of course extinguish all the tubes. You must then inspect the tubes and determine which one is at fault. Such cases are fully covered in your operating instruction book, which it is advised that you study and pay strict attention to.

Amplifier troubles other than those I have named are rare, though of course they do occur. If you have any trouble which you cannot handle, you must, of course, SOS the Service Engineer.

Keep plugging, brother. The top is reached only by climbing.

The Sound Gate

THE "sound gate" is an assemblage of springs and pressure shoes designed to hold the sound track snugly against the sound aperture, much as the projector gate or "film trap" holds the film in place over the projector aperture.

The sound gate must have careful attention from the projectionist before he threads any film into it. If this attention is not given, the sound gate may and probably will "get back" by seriously injuring or perhaps entirely ruining a lot of sound track, which means, in effect, ruining just that much of the print.

The whole purpose of the sound gate is to hold the sound track snugly against the sound aperture, which faces the photo-electric cell. Because of this there is always the tendency for the pressure exerted at this point to cause the metal, polished though it be, to pick up a deposit of emulsion or of the surplus cement often found in dried condition upon the surface of the film at carelessly made splices.

With some apparatus such a deposit cannot occur in such way as to injure the sound band. With other apparatus such a deposit may begin at any time. It cannot, of course, be remedied until the film being projected has been finished, but is not likely to grow sufficiently to do damage during that period. It is evident that, if permitted to remain, it will inevitably increase in size and soon may become large enough to inflict serious damage to the sound track, or even to entirely ruin it, which, of course, means ruin to the entire film, because the picture part is useless without its sound track.

If the apparatus is such that deposit is possible, it is imperatively necessary that the projectionist make it his invariable rule to carefully run his finger over the metal above and below the sound gate aperture before he threads in a film. Do not fail in this. A single failure may cost the total ruin of an entire reel of film.

If there is a deposit, no matter how small, remove it before threading in the film, but do not scratch it off. **Never, never, never do that!** If you do, and more especially if you are foolish enough to use a knife blade or other steel instrument, you will inevitably roughen the metal surface and thereafter may look for trouble constantly from deposits.

Remove such deposits with a wet cloth, or by dampening your finger tip. Use water and nothing else! It will soften such deposits immediately. It is the only right, safe way!

KEEP THE ENTIRE SOUND TRACK SCRUPULOUSLY CLEAN.—In addition to the necessity for keeping the sound gate sound track clean, it is almost equally necessary that the entire track the sound track passes over from upper to lower reel be carefully examined at least once every day.

Beginning at the upper magazine, examine the fire trap rollers to see that they revolve freely, and are perfectly clean; also that they have no flat spots, though the latter would not, of course, occur unless a roller had been in one position (not turning) for quite some while. Examine the surface of the chute the film passes through in its exit from the upper magazine, making certain that its surface is smooth and free from all deposit. Films have been badly injured by deposits occurring here. Not all projectors have such a chute.

Passing on down, it is well to carefully examine all sprockets and sprocket idlers to make certain the faces of the sprockets are perfectly clean—particularly the intermittent and sound sprockets. If there is any deposit, a good stiff toothbrush is best to clean it off with. If it be dampened with kerosene the deposit will come off more readily. Give the idler rollers a drop of thin oil once each day.

Continuing down, **examine the sound sprocket with particular care,** because any deposit on its face will throw it out of round and create a more or less objectionable effect upon the sound reproduction, according to the depth of the deposit. **This sprocket should be carefully examined at least once a day.** Because you find no deposit for some while, either in the gate or on the sound sprocket, don't get careless. If you do you may suddenly find yourself with a reel of film ruined on your hands.

In addition to what has been set forth, the fire trap rollers of the lower magazine must be examined each day, and any and all other places where the film does or may rub against metal in its passage through the projector and sound reproducing mechanism.

SOUND GATE APERTURE.—Keep it perfectly clean. Dirt or dust in it will reduce sound volume and injure its quality.

The pick-up optical system must be kept scrupulously clean. As elsewhere instructed, clean and polish the outer surface of the exciting lamp each day. Clean the single outside surface of the slit assemblage condenser every day. In fact, clean every glass surface exposed to the air once each day, and do a good, but very careful job of it, too.

Be proud of the fact that all during the year it was not necessary to send for a service engineer.

Threading Sound Film into the Projector

IMPORTANT NOTE.—In what follows, when the term "lower sprocket" is used it means the projector mechanism sprocket next below the intermittent sprocket.

IN projectors fitted with a sound attachment for the use of film carrying the sound record, there are the usual sprockets, namely, the upper, the intermittent and the lower. In the sound attachment is the "sound" sprocket, which moves the film past the sound aperture; there may or may not be an added sprocket in the lower magazine. There are also idler rollers, "spin wheels," etc., their number, kind and location varying with the type of the sound attachment.

The "sound sprocket" runs continuously, and must run with a perfectly steady rotary movement. Also it is absolutely essential that it be kept scrupulously clean. Any deposit upon its face will tend to throw it out of round and cause the film to move past the sound aperture with an uneven movement.

Threading the film into any projector mechanism and sound attachment presents one vital problem, namely, the setting of the film in such manner that there will be exactly fourteen and one-half (14½) inches of film between the center of the projector mechanism aperture and the center of the sound gate aperture. **Unless this be the exact condition, there will be an out-of-syn-**

chronism effect in proportion to the excess amount of film between the apertures, or the lack of sufficient film between them.

This is taken care of in the setting of the lower loop—the loop between the intermittent sprocket and the lower sprocket—which item must have your very close attention in threading.

Figure 392.

Examining Fig. 392 you will observe that whereas A B and A′ B′ are located precisely the same distance apart, still if the lines connecting them be film, then there would be considerably more film between A′ and B′ than between A and B. That is self-evident, and that is precisely the situation encountered in threading sound film.

As has been said, there must, if there is to be perfect synchronism between sound and motion, be exactly 14½ inches of film between the centers of the two apertures. This is because the sound record which "goes with" the action at any given point in the film is exactly that distance from the action itself, and in advance of it as the film is threaded into the projector.

Again examining Fig. 392 you will understand that if the curves be made larger between A′ and B′, then

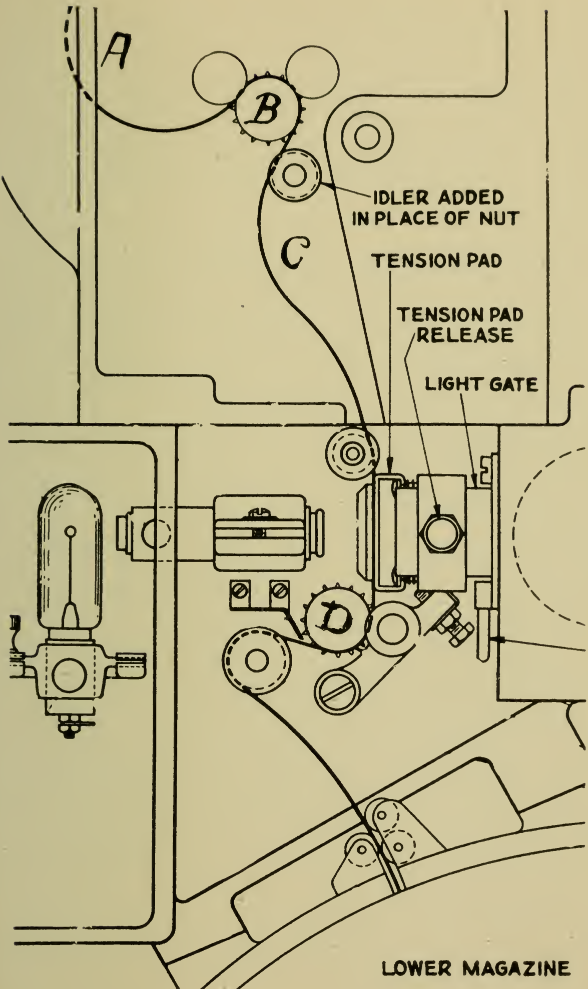
A
B
IDLER ADDED
IN PLACE OF NUT
C
TENSION PAD
TENSION PAD
RELEASE
LIGHT GATE
D
LOWER MAGAZINE

Figure 393.

there would be more film between the two points. On the other hand, if they be made smaller, there would be less film. Examining Fig. 393, which is the film as threaded into a Western Electric sound attachment mounted upon a Simplex projector, you will see that if loops A or C be made either larger or smaller, then the amount of film between the two apertures would be altered.

Western Electric employs two loops, namely, loop A, Fig. 393, and loop C, Fig. 393. Loop C is made by setting loop A exactly the right size, which is gauged by its relation to the lower fire shield, as shown in Fig. 393, then stretching the film down through the opened sound gate and down past the sound sprocket tightly, and then **slacking up exactly two sprocket holes,** attaching it to the sound sprocket, closing the sound gate idler and the sound gate itself.

Different procedure is followed in this respect with different makes of apparatus. Some have no loop C at all. Whatever the procedure, however, the setting of the lower loop (loop A, Fig. 393) exactly the right size is of extreme importance. Your operating instruction book and the installation engineers will advise you just how to do it. My chief concern is to impress upon you the necessity for the utmost possible exactitude in following those instructions. Even so little as one sprocket hole "out" in the matter of setting the lower loop will injure the result in synchronism.

The Exciting Lamp

NOTE.—This applies equally well to all makes of sound-on-the-film apparatus.

THE exciting lamp (also by some termed the "sound lamp") is the light source supplying illumination to or for the film sound track in the motion picture projector sound pick-up system. It is imperatively essential to good results in sound reproduction and projection that the illumination it supplies be steady, and of exactly the correct value, which latter is gauged by the amperage flow through its filament.

Let it be clearly understood, however, that passing the correct current flow through the lamp filament will not insure good results unless the lamp itself is in perfect condition, nor will good sound results be had with a perfect lamp and correct amperage unless the slit optical system, which includes all lenses between the light source and film, be in correct adjustment, clean, the light correctly adjusted upon the slit and properly focused upon the sound track. In addition to all this it is essential that the image of the slit be correctly centered sidewise upon the sound track, so that it will not extend either into the picture portion of the film or into the edges of the sprocket holes.

Further along I shall advise you how to make a practical test for sidewise centering of the slit light for Movietone film.

To summarize, the following requisites are essential to perfect results: (a) That the exciting lamp itself be in perfect condition. (b) That the exciting lamp filament amperage be at exactly the correct value, which same may be obtained from your operating instruction book or from your Service Engineer. (c) That the light be correctly adjusted (not focused, but adjusted) upon the slit. (d) That the light from the slit be properly focused upon the film sound track. (e) That the slit image be correctly centered sidewise at the film sound track, and (f) that the sound gate aperture, slit assembly lenses and exciting lamp all be perfectly clean.

Let us now examine the exciting lamp, three pictures of which appear in Fig. 394. These are the type of

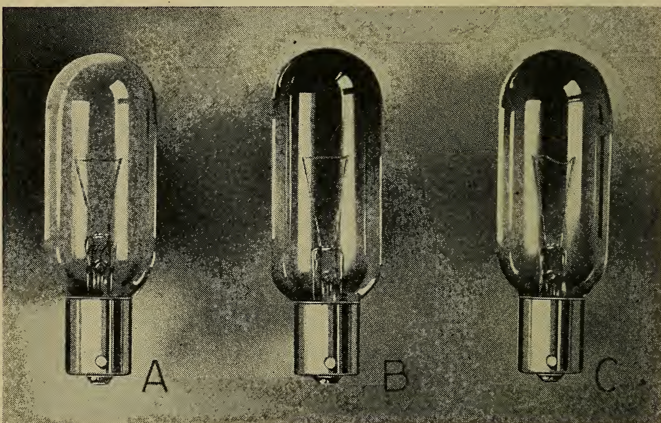

Figure 394.

exciting lamp used in all the sound reproducing equipment dealt with in this book. A is a lamp in perfect condition. Glass clear and unclouded; filament perfectly straight. B is a lamp which has been used entirely too long. The interior of its globe is badly blackened by deposit, though its filament still is in apparently perfect condition. C is a lamp, the filament of which is badly sagged; also its globe is somewhat blackened by deposit. **It is worse than foolish to keep lamps in use until they get into such condition as shown in B and C, Fig. 394.**

The man who takes pride in his work and values high grade service above his own ease, will remove his exciting lamp, polish its outer surface and **carefully examine the glass for discoloration and the filament for signs of sagging.**

It is very poor business to try to "save" a few cents in exciting lamp cost, when by so doing you must and will inevitably work injury to the sound. **Discard exciting lamps the moment they show any signs of filament sagging or discoloration of the globe. These defects not only lower the sound volume, but also injure the sound quality.**

In considering the results of filament sagging it will be well to remember that this light source is used to project a very thin line of light, described elsewhere, and that a horizontal line in its beam representing the center of the filament will carry the greatest illumination value. If this be true, and you may readily see that it is, it then follows that if the filament be sagged in any degree, no matter how slight, the most brilliant line of illumination cannot possibly be exactly adjusted upon the slit.

A TEST.—I promised I would tell you how to make a really practical test for sidewise adjustment of the slit image upon the film sound track, in order to make certain it is not too far to the right or left. To do this you must obtain some Eastman **negative** film. Ten feet should last you quite a long while. I think likely you may get it from either Fox-Case Movietone, Tenth Avenue at 54th Street, New York City, or from RCA Photophone, 411 Fifth Avenue, New York City. Certainly it may be had from the Eastman Company, Rochester, N. Y.

This film will look just like the white leader and trailer used on positive prints, but that sort will not do at all. You must have negative stock.

Having obtained the film, just thread it into the sound gate as you would a positive print, with the emulsion side toward the light, and close the exciting lamp switch. Let the light from it shine on the stationary film while you slowly count ten, then turn the projector flywheel so as to move the film the fraction of a sprocket hole, and again let the light shine upon the stationary film while you count ten. Repeat this, say, half a dozen times.

Remove the film and, examining the same carefully, you will find a series of tiny lines at the portion which passed over the sound gate aperture (you must look closely to see them). They will be the imprint of the image of the slit. You will do better if you use a condenser lens or other magnifying glass to make the examination. You may now see just where the slit image registers sidewise, and by cutting off a bit of sound film and comparing by laying it on the test strip, with sprocket holes perfectly matched, you may know whether or not the slit image is correctly centered sidewise.

WARNING.—Should you start projection and discover you have no sound because you have not lit the sound lamp, **don't light it** until you have first retarded the fader to zero. Then light it and gradually advance the fader to its normal setting. Should you snap on the sound lamp without first retarding the fader you will have a roar of sound which will be very unpleasant.

AN EXTRA EXCITING LAMP READY.—It is quite obvious that it would be impossible to remove a sound lamp that had burned out, insert a new one and adjust it properly in its socket while projection was in process. That would require several minutes. It also is evident that it always is possible, however improbable it may be, that an exciting lamp will fail right in the middle of a reel.

Those using Western Electric equipment may guard against such embarrassment as attends shutting down the show while a new exciting lamp is installed, by keeping an extra lamp bracket handy, where it may be secured instantly, with a spare lamp adjusted in it all ready for use. All that is then necessary in case of failure of the exciting lamp is to pull out the lamp bracket and shove in the new one, **first having retarded the fader to zero.** The whole operation may be performed, if the spare lamp and bracket be located handily, in a matter of five or six seconds, including bringing the fader back up to operating position.

ADJUSTING LAMP IN SPARE BRACKET, WESTERN ELECTRIC EQUIPMENT. — The spare lamp may be adjusted in the spare bracket as follows: The lamp base has a pin in its side, which same is passed through a slot in the socket as the lamp is inserted. To insert a lamp, first make sure the clamp screw D, Fig. 395, is loosened. Insert the lamp in the socket, shoving it down until the pin clears the slot and giving the lamp a turn to lock the pin in the place provided. It is imperative that the lamp filament be exactly parallel with

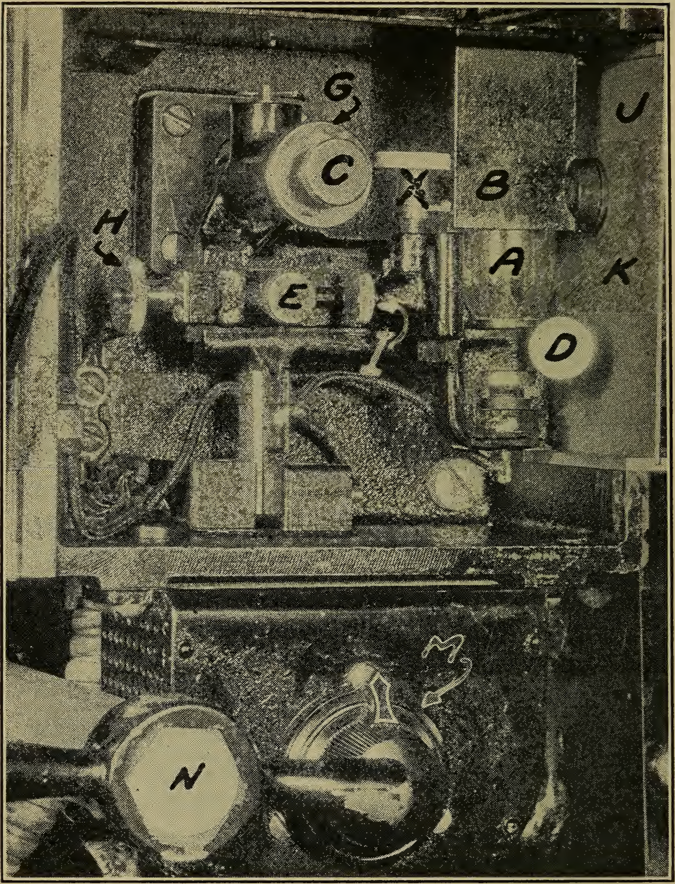

Figure 395.
View of Exciting Lamp Compartment Western Electric Reproducer Set.

A—Exciting lamp. B—Shield to protect projectionist's eyes from glare. D—Screw by means of which existing lamp may be clamped into its socket. J—Partition between exciting lamp and sound gate compartments. It may be removed merely by pulling it out toward you. C and G Thumbscrew enabling the moving of the lamp sidewise and clamping it into place when adjustment is finished. X—Thumbscrew by means of which exciting lamp may be raised or lowered vertically. When adjustment is completed it is clamped immovable by screw 1. By means of thumbscrew H, the lamp may be moved forward or back for focusing the light upon the slit. This adjustment is clamped immovable by means of thumbscrew E. M, located under this compartment, is the dial by means of which current is adjusted to the proper value, as shown by the ammeter on the front of the compartment door. This current must be maintained exactly at the amount set in your instruction book. Any alteration in the current value would cause over or under illumination of the sound track and change the volume of sound. Be very careful about this matter. N is the handle by means of which the angle of projection may be altered when using the Western Electric universal projector base. The insulated wire runs to the ammeter on the compartment door. The sound gate compartment (Fig. 396) joins the exciting lamp compartment on its right. I have separated them in order to enable us to have a larger picture of each.

the face of the slit lens tube—parallel with the film. See to it that it is so.

Having inserted the lamp into its socket, shove the bracket into place, make certain that the lamp filament is parallel with the face of the lens tube, as above set forth, and tighten clamp screw D.

Next, loosen clamp screw I, Fig. 395, by means of adjusting screw X, raise or lower the lamp until the slit in the lens tube is in the center, up and down, of the light beam. Tighten clamp screw I. Next loosen clamp screw G and, using adjusting screw C, move lamp until the slit is in the center of the light beam sidewise. Tighten clamp screw G.

You now have the exciting lamp properly located up and down and sidewise, but it still remains to move it backward and forward until the slit is correctly focused upon the sound band, which may be done by means of adjusting screw H, Fig. 395, which is clamped by means of screw E.

If all this has been properly done, the slit image should be sharp and brilliant and in proper location upon the film sound band, but this latter should be tested by means already described, using negative film.

NOTE.—This is not designed to take the place of the instructions contained in your operating instruction book. I have set it forth so that those thousands who are not yet handling Western Electric sound apparatus may get some understanding of the apparatus and its correct adjustment. I strongly recommend to you that you read and study the operating instruction book issued to you by Electrical Research Products and RCA Photophone, De Forest Phonofilm, Powers Cinephone and

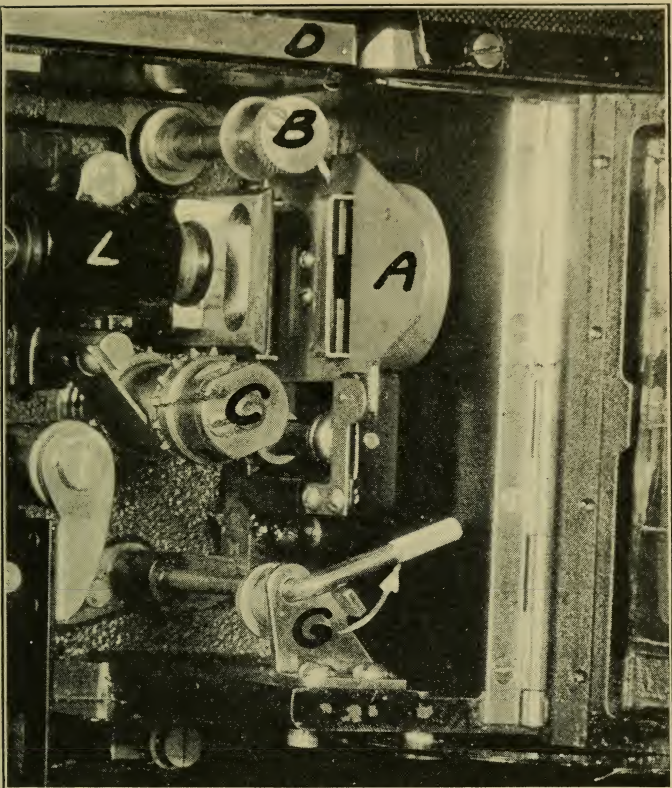

Figure 396.

Sound Gate Compartment Western Electric Reproducer Set.

This compartment is joined upon its left by the exciting lamp compartment. They have been separated for purposes of illustration because if they were kept together the page illustrations would not permit of sufficient enlargement to enable you to see the details.

D is the slit in the projector mechanism base through which the film comes down from the lower sprocket of the projector mechanism. B is a guide roller. A is the sound gate assemblage containing the usual tension springs, etc. This assemblage may be pulled out sidewise in its entirety. C is the sound sprocket which moves the film past the sound aperture. It is very essential that this sprocket be kept immaculately clean. Dirt adhering to its surface will have the effect of throwing it out of round, insofar as concerns the film, and this will result in injury to the sound. G is the tension pad release—the lever by means of which the sound gate may be opened or closed. L is the slit assembly.

others. This book is designed more to give you instruction in and an understanding of fundamentals, than to supply actual, detailed operating instructions.

A FURTHER TEST.—After you have completed the setting and adjustment of the exciting lamp in Western Electric equipment, pull out sound gate assemblage A, Fig. 395, and, holding a sheet of white paper over the opening thus disclosed, project the light from the exciting lamp to it. You will find on the paper a rectangle of light with heavily rounded corners. Its illumination should be clear and even. If it is not, then move the lamp up, down or sidewise until all shadows disappear and the field is evenly illuminated.

Having thus adjusted the spare lamp in its socket, you may remove it with assurance that, should the lamp in use fail, you may shove in the spare and proceed with the show. It is, of course, understood that the supporting bracket may be slipped off its support and slipped back on again without disturbing any of the adjustments.

Description of existing lamp installation and adjustment will be found in the description of each kind of apparatus.

Horns and Loud Speakers

I BELIEVE it is right and proper to differentiate between "horns" and "loud speakers." True there are points of similarity, but also there are many points of difference. Up to now the term "horn" and "loud speaker" have been used rather indiscriminately, which is, I think, a mistake.

Great confusion arose and much harm was done in the earlier days of the industry by carelessness in the matter of nomenclature, the harmful effects persisting to this day. Surely that error should not now be repeated, and so far as it is possible, in my writings it will not be repeated. Unfortunately, however, up to the time of the preparation of this work, the Society of Motion Picture Engineers, which now is the authority in motion picture nomenclature, has taken no action to fix and standardize nomenclature with regard to sound apparatus. I therefore am obliged to use such terms as are now in use, which same may possibly be later altered.

There are at this time two very different types of sound projectors in use in connection with motion picture work. One consists of a small metallic receiver coupled to a horn of considerable dimensions. The other is a small metallic receiver coupled to a cone of relatively small dimensions.

For the purposes of this work I shall call the first a "sound projector" and the latter a "loud speaker." Both really are sound projectors, of course, but by this means confusion in terms may be avoided. Whenever or wherever the term "horn" is used, the large-mouthed shell attached to the receiver of a sound projector is meant.

We will first examined the loud speaker used in connection with Western Electric equipment, which consists of a small metallic receiver and a horn of carefully calculated length and shape.

THE RECEIVER. — First we will consider the receiver, a diagrammatic cut-away view of which we have in Fig. 397. This explanation of the receiver is not made with any idea that the projectionist will ever be called upon to repair or adjust receivers, but from the broad viewpoint that men should have an understanding of the construction and the functioning of every part of the apparatus they have charge of and must work with. Unquestionably such knowledge adds to their efficiency, and to the efficiency with which they will be able to handle the equipment.

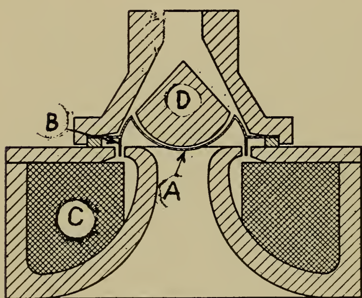

Figure 397.

Diaphragm A, Fig. 397, is made from very thin aluminum alloy. Its central portion is cupped into portions of two spherical surfaces, as you may see by examining

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Fig. 398 shows the receiver unit complete, all ready for attachment to the horn. B is the receiver front plate. C is the part which is mounted in front of B to complete the sound chamber, the two faces of which are shown at X. The receiver unit has a threaded boss permitting its attachment to the horn. B′ and C′ indicate parts B and C in place upon the receiver, where they are locked into position by nut D.

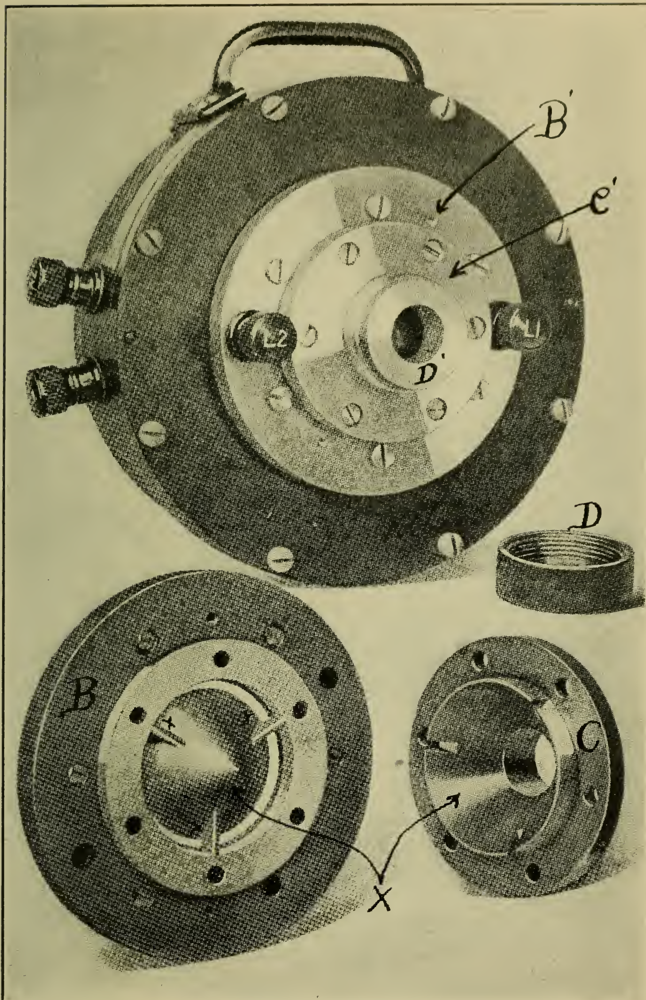


Figure 398.

Front view Western Electric Horn Receiver 555-10 and its air chamber.

the figure. B is the coil which, energized by the main or field coil C, drives or energizes diaphragm A. D is the damping plug, the purpose of which is to shape the tone chamber for proper distribution of the air pressure waves. It contributes very largely to the efficiency of the unit. It does not lie upon the diaphragm, but is supported by three radial ribs, X X X, B, Fig. 398.

Driving coil B, Fig. 397, is composed of a single layer of aluminum ribbon, wound edgewise. It is attached to the lower extension of diaphragm A, Fig. 397, as is shown at B D E, Fig. 399. It reacts between the pole pieces between which it is located, which later are energized by main field coil C, Fig. 397, which is itself energized by a twelve (12) volt storage battery, and by such reaction operates or drives the receiver diaphragm.

Driving coil B has high carrying capacity because of its single layer construction, the small amount of insulating material required, and the consequent high rate of heat dissipation.

Diaphragm A, Fig. 397, is cupped in order to provide stiffness or rigidity sufficient in amount to enable it to move against the air column of the horn as a solid plunger, which it does. This has the advantage of securing maximum efficiency and uniformity of air action by moving the entire area of the base of the air column as a unit.

The manufacturer claims that the efficiency in converting electric energy into sound energy by this unit is very much higher than it is with the ordinary horn or loud speaker unit; in fact fifty per cent as against a one per cent average heretofore obtained. The claim also is made that the power input this unit will carry is likewise increased from about five watts to thirty watts, all of

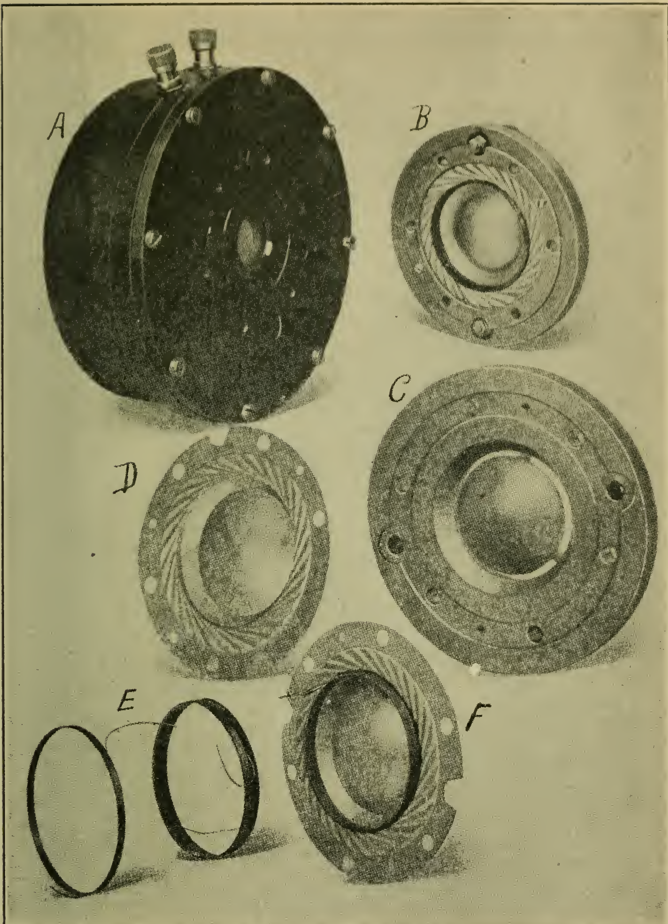


Figure 399.

A still more detailed illustration of the receiver.

A—Complete receiver, Fig. 398, rear view.
B—Diaphragm clamped in its supporting ring.
C—Front plate of receiver.
D—Diaphragm, front view.
E—Actuating coil of diaphragm.
F—Diaphragm, rear view.

which means that the output energy is from 250 to 300 times as great as that previously available.

We have now examined details of the construction of the receiver and have seen about how it operates. Let us next examine into the matter of what it does.

It is the receiver which forms the connecting link between the current coming from the Photo-Electric Cell, through the amplifiers, and the air. In other words it is the thing which receives the electric impulses coming from the amplifiers and translates or changes them into air vibrations audible to the human ear.

You have already been told how the air vibrations coming from the voices, instruments, or what not, in the recording room, operate the microphone diaphragm, and thus set up electrical impulses which are their exact equivalent in electrical form. We now have the process exactly reversed. The electrical impulses coming from the amplifiers operate the receiver diaphragm and set up air vibrations which are their exact duplicate in the form of sound waves.

THE HORN.—It is rather difficult to explain the true function of the horn in language which can be understood by the non-technical man. However I will do the best I can.

If you remove the horn, leaving only the receiver, and put the receiver into action, you will find there will be audible sound. In fact if the receiver be worked to the limits of its capacity there may be a great deal of sound. You will be able to distinguish the words, music or whatever is then being reproduced quite plainly, but the sound will nevertheless be very unsatisfactory, because it will be thin, shrill and without resonance. If it be voices,

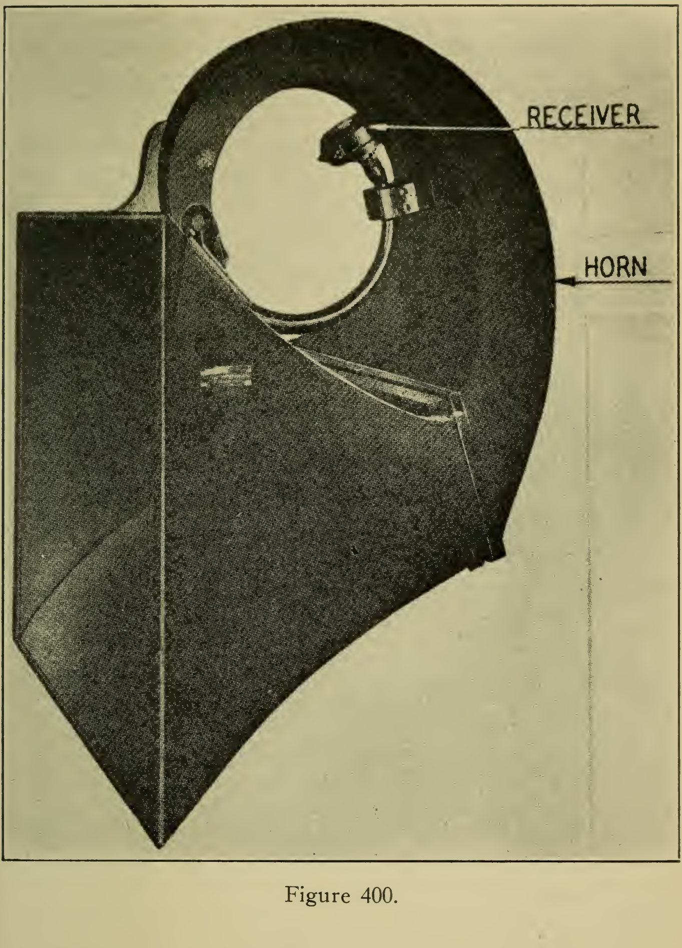


Figure 400.

they will sound like those you would expect to hear were pygmies about two feet tall talking. It will be entirely unnatural.

This, we will be convinced by a moment of consideration, cannot possibly be through any fault of the receiver itself. What is coming from it is all there is. The receiver can send no more through with a horn attached than it does without the horn attached. That is plain common sense, yet if we, without changing anything else, attach the horn, we find the thin shrill sounds to instantly come forth with full resonance, and apparently with enormous amplification. Naturally we wish to know why this is so.

As nearly as I am able to put the thing into understandable words, this is what takes place. The receiver alone does transmit all the sound there is, but it is unable, unaided by a properly constructed horn of proper length, to connect to or deliver to the great body of air any but the higher sound wave frequencies.

What the properly constructed horn of proper length does is to form a connecting link between the receiver and the outer air for those same high frequencies, **plus the low frequencies.** In other words it makes available to the air all the sound wave frequencies within range of the horns, which in motion picture practice run as low as sixty, or even somewhat lower.

Please do not ask me why this is so. I don't know, and by that same token I am not at all certain the experts on such matters know either. We do know, however, that that is the fact.

In constructing horns it has been found necessary to have the walls formed in an exactly calculated shape known as an "exponential curve." If you examine the walls of a horn you will see they do not expand in a straight line, but in a curved one. In this I am not referring to the fact that the horn as a whole is coiled up. That is merely to economize space and to permit of their installation on stages and in places where a straight horn could not be used at all. I refer to the "flare" of the walls.

Both the shape and length of a horn have much to do with the volume and quality of the sound delivered to the outer air. If either be wrong, then the sound may (a) lack volume; (b) be "tinny"; (c) be "boomy" or muffled.

The secret of the action is this: The tapering column of air contained in the horn "loads" the diaphragm of the receiver. The diaphragm transmits its vibrations to the tiny tip of the air column, and these vibrations are all transmitted increasingly through the confined column of air until when the outer end of the column is reached there is sufficient energy and area of vibration built up to set the great body of air in the auditorium into equal vibration.

There, gentlemen, the engineers will doubtless rave about the inaccuracy of that description, but just the same it conveys the main **idea.** It is exactly what takes place, technically inaccurate as it may be. If I told you in engineering language, I might just as well write it in Chinese, so far as concerns the average man.

Referring again to the "exponential curve" (horn side), experiments over a period of years have established the fact that only when this curve is used will all the various frequencies reproduced by the receiver, down to the lowest the sound projector will efficiently handle, be delivered to the outer air with equal efficiency, hence without appreciable distortion.

If the cross-sectional area of the air column within the horn did not taper from point to point of its length in exact accordance with the exponential curve—if for example the horn tapered with flat, straight sides, top and bottom, then certain frequencies made available to it by the receiver would be delivered to the outer air less perfectly than would others, which of course would mean distortion of or in the sound, taken as a whole.

The production of a large volume of sound from a receiver of sufficient capacity, "fed" by amplifiers of sufficient capacity, presents no special difficulties. In the matter of volume alone, the size of the horn is not of large importance.

VOLUME.—However, let us not misunderstand the nature of "volume." There is considerable tendency to error in this item. There may be plenty of volume to fill an auditorium, yet little at the frequencies we need.

Take a child's tin whistle, for example. It might fill a theatre auditorium with an ear splitting shriek, but the average man would say it had no volume, whereas a bass drum he would say had enormous volume. He would recognize the fact that while the drum would not have the piercing loudness of the whistle, it would nevertheless be radiating much more acoustic energy. If sufficient energy be applied, a horn of relatively small size could be made to fill a large auditorium with sound. However, the sound would be unsatisfactory, because of the fact that the small horn could only transmit to the outer air the limited range of frequencies such as a horn of its kind could handle. There would be plenty of sound all right, but like the tin whistle volume, it would be "not so good." The low, or bass, frequencies would be lacking.

In considering volume it is well to understand that most of the acoustic energy is associated with the low frequencies. If you will take notice, you may find the next time you are present when a great pipe organ is thundering forth its bass notes, or when a bass drum is beaten, you not only hear the sound but also in a way seem to feel it.

This is because of the intensity of air vibration set up by the low frequencies. They may actually be no louder, or even not so loud as the more shrill boy's tin whistle, but they give the impression of power.

It therefore follows that a bass note sets up more acoustic energy than does its higher frequency brother, and that therefore the bass horn, for example, produces more acoustic energy than does the tenor horn, because it brings out the lower frequencies.

HORN LOCATION.—This is a very important matter for the reason that the horns now in use for the reproduction of sound in theatres are quite directional. By this it is meant that they direct the greater portion of the sound emanating from them in what we may term a "beam," the same covering an effective angle of only about forty degrees.

This being the fact it follows that especially in very wide auditoriums the direction in which the horns are "pointed" is highly important. The effect of horn setting, insofar as pertains to the **exact** direction in which they "point," should be the subject for very careful study and experiment in each theatre at the time of installation, when the setting best adapted for that auditorium has been finally determined, that setting must be **exactly** maintained, remembering that a very slight sidewise alteration of a horn may cause a considerable alteration in effect at the rear of a deep auditorium.

This matter of horn location is attended to by the installation engineers and the setting determined by them to be best should not in any degree be altered without most excellent reasons, and then only after consultation with the Service Engineer, and preferably with him present.

In this connection I am personally inclined to believe the type of horn now in use for theatre sound projection is not the best type. However, of that I am not certain. Only the future will determine that point. Engineers are working hard and continuously, seeking improvement in every part of sound apparatus. Doubtless the next year or two will see very many improvements accomplished.

If at any time the theatre manager and projectionist conclude that the sound distribution is not what it should be, then it is very right and proper to bring the matter to the attention of the Service Engineer and ask that further experiments be made to determine the point. It is also possible, though not, perhaps, advisable, for the manager or projectionist to themselves make experiments looking to improvement in sound distribution by altering the horn positions. However, if this be done **it is imperatively necessary before any move is made, that the exact present horn position be marked, so that if the experiment proves unsuccessful, the horn or horns may be replaced at exactly their original location.**

The best horn location is the one which will give the best average results in all parts of the auditorium. If the horns point too straight out, there may and probably will be a high sound volume in the center of the auditorium, with more or less fade-away at the sides. If they be made to point too much down, then sound in the balcony, if one there be, will not be sufficiently loud when it is correct in the lower floor, or vice versa.

In wide auditoriums the best purpose is served with the horns at the left of the screen (left as one faces the auditorium), pointing slightly to the right, and those on the right pointing slightly to the left, the amount being determined by very carefully made experiments.

In theatres where, because of vaudeville or for other reasons, there must be a screen down front, whereas the regular screen is located at the rear of the stage and is permitted to remain in permanent position, with the horns behind it, if the front screen is only to be used for a short interval while the stage is being cleared after the vaudeville is finished, then it may be permissible to use the rear horns for the front screen, provided it be necessary to use sound during the interval. It usually is possible to use silent pictures during this short interval, however.

On the other hand, if the front screen is used to screen an entire feature before a vaudeville show starts, as is the case in some theatres, and a rear screen used to again screen it after the vaudeville is off, then it will be necessary to have two sets of horns, those serving the front screen to be flown. If horns are flown, then the ropes by means of which they are raised and lowered should have proper markers, which may take the form of knots in the ropes, so that each time the horns will be lowered to exactly the same height from the stage floor.

When horns are carried on horn towers mounted upon dolly trucks, then the stage floor should be marked to show the **exact** location of each truck. In addition to painted floor markings it is well to provide suitable means for anchoring the truck in exactly correct position. One simple method is to screw two stout eye-bolts into the side of the truck timber near the floor, one a few inches above the other, at two corners of each truck. Then place the truck in exactly correct position and, having provided a suitable substantial bolt to drop through the eye-bolts, bore holes in the stage floor so that the bolts will drop through them, and thus not only compel the correct placing of the trucks, but insure them against being moved out of position until the bolts have been raised.

MANAGER'S INSPECTION.—In theatres where it is necessary to move the horns to accommodate tableau or vaudeville, it will be well that the manager appear on the stage and inspect the horns occasionally. Stage crews are not, it grieves me to say, always quite as careful as they might be about such things, and unfortunately the "aw that's good enough" won't work well with horn location, unless it be applied **only** to horns in exactly the right position.

Fig. 401 is a diagram of an auditorium fifty feet wide by eighty deep, drawn to scale. A B is a screen sixteen feet wide. D C is the center of two horns. Solid black lines J J represent the acoustic axis of either horn when they are set with their openings parallel to the screen surface. Solid lines E E and F F represent the outline of the sound beams when the horns are thus set. These sound beams each include approximately a forty degree angle.

Broken lines I I represent the acoustic angle of the

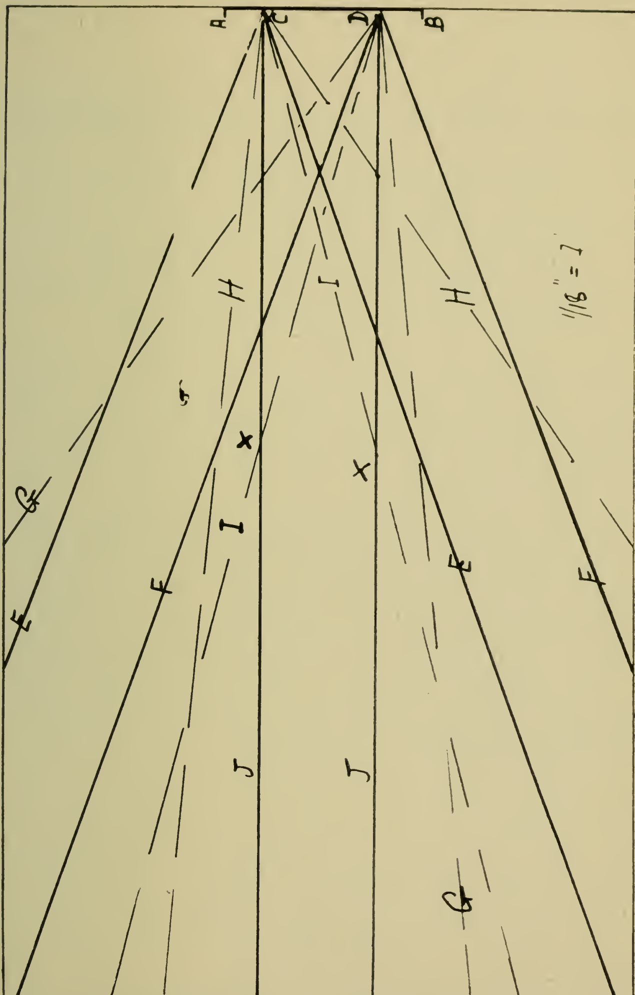


Figure 401.

same horns when they are each angled in toward the center fifteen degrees. Broken lines H H and G G represent the beam outlines under this condition.

At first glance it may seem that there would be slight difference in effect as between the two settings. However, a closer study of the diagram will, I think, convince you that the angled horns will give a decidedly better distribution of sound, or that they at any rate should do so. You will note, for example, that with the horns set straight, the acoustic axis of both are parallel throughout the auditorium, and only a short distance apart.

Naturally the greatest volume of sound will be nearest the acoustic axis of each horn, hence it follows that with such a setting the greatest volume of sound would be concentrated in the center of the auditorium throughout its entire length.

With the horns angled, however, you will observe that beyond point X X the greatest volume of sound is distributed over a considerably greater area. In Fig. 401 no attempt has been made to indicate the best possible setting for an auditorium of that shape and dimensions. It has only been intended to illustrate the general effect of angling the horns somewhat in toward the center, so that their "beams" cross each other.

Storage Batteries and Their Care

NOTE.—I desire to express appreciation to the Electric Storage Battery Company, makers of Exide Batteries, and particularly to Mr. John McGuinness of that company, for aid in preparing the matter appearing under the above title. It has the official approval of the Electric Storage Battery Company and of Mr. McGuinness himself.

THE storage batteries you use in sound reproduction are nothing more or less than an auxiliary or secondary power source. They are an arrangement by means of which, through the chemical reaction between certain substances, it is possible to "store" electrical power, and, within certain well defined limits, retain it in storage for future use. By the use of such a storage arrangement we are enabled to have a thoroughly dependable, quiet and steady source of electric power which, once charged, is entirely independent of the power lines until such time as its energy is exhausted to the point where further storage (charge) is necessary.

It is of course necessary that power be taken from some generating source and stored in the battery, before power can be taken from it. A storage battery generates no power in itself. Putting power into a battery is termed "charging." Only direct current may be used to charge batteries. It therefore is necessary, if the power supply be A. C., to have some sort of device by means of which it may be changed to direct current before attempting to use it for battery charging. This usually is accomplished by what is called a current rectifier, or a "rectifier."

The action of a storage battery is simple and readily understood, once you understand the underlying principle, in which understanding it is very likely a brief history of the discovery of the principle involved will greatly help.

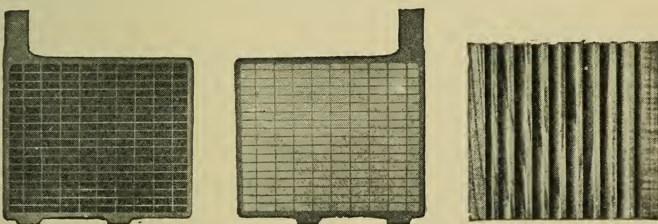
An investigator named Planté, a Frenchman, by the way, discovered that if two sheets of pure lead be placed in a mixture of sulphuric acid and water of certain strength, and one of these plates be connected to the positive and the other to the negative poles of an electric generator, after the generator had been operated for a time, the lead plates could be disconnected from the generator and would themselves serve as a source of electric power.

He found, also, that the power discharged by the plates after being disconnected gradually diminished and finally ceased entirely, but that if the plates be again connected to the generator, as before, and the generator be again operated for a time, there would, after disconnection, again be power available in the plates themselves. He, in fact, found that this operation could be repeated many times; in fact, almost indefinitely, provided certain precautions be taken in the speed of charging, keeping the sulphuric acid-water mixture high enough to completely cover the plates, etc.

This was in fact the first crude storage battery using the principle now used in all storage batteries.

Further investigation by Planté disclosed the following facts: He found that after the two lead plates immersed in the acid-water bath were connected to the generator, and after the generator had been operated for some time, a compound known as lead peroxide had formed on the surface of the plate connected to the positive terminal of the generator, which plate he very properly dubbed the "positive plate." He further found that the surface of the other plate, called the "negative plate," had been changed into spongy or porous lead.

Planté further discovered that when he disconnected the two plates from the generator and used them as a power source, not only was he able to get power from the "battery" thus formed, but also the lead peroxide formed on the positive, and the spongy lead of the negative plate reacted chemically with the sulphuric acid-water solution (electrolite) so that he had two plates completely covered with lead sulphate.



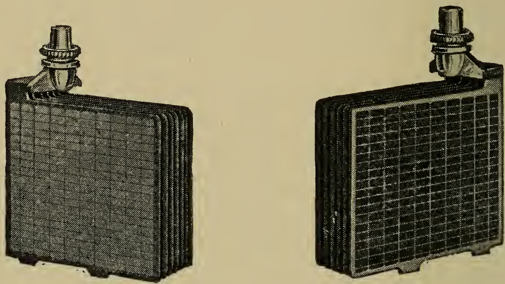
A. Positive Plate B. Negative Plate C. Wood Separator

Figure 402.

When he again connected these sulphated plates to the generator, he found that in due time they returned again to their original condition, the positive being again coated with lead peroxide and the negative again pure, spongy lead.

That is an explanation of how the thing works. It is the principle underlying all lead-acid storage batteries. It works precisely the same as it did when Planté discovered it over in France something like forty years ago.

Planté reasoned the action out as follows and no one has yet discovered any fault in his reasoning. His view was that when he connected the two lead plates to the generator, it was the electric current flowing from the



D. Negative Group E. Positive Group

Figure 403.

generator which had caused the lead peroxide to form on the positive plate and made the other plate pure, spongy lead. That when he disconnected the generator and then connected these two plates to an electric circuit, the current which flowed was the result of a chemical action in the battery. That is, the sulphuric acid combined chemically with both the positive and negative plate to form lead sulphate on each. The electric power was given off as this chemical reaction went on and when the chemical action stopped, due to all the lead peroxide of the positive and pure lead of the negative plate being converted to lead sulphate, the electric power also stopped.

We can therefore understand that the current which flows from a charged battery through an electric circuit, is produced by the chemical action which goes on in a battery; that is to say, the chemical formation of lead sulphate in both plates. The battery is discharged when the current ceases to flow, which means that the chemical action in the battery has stopped. We can now reverse the procedure, force current through the battery and convert the plates back again into their original chemical condition. This is called charging.

When the current has been forced through the battery long enough, the positive plate is again in the chemical form of lead peroxide and the negative plate is again pure lead. In other words, the lead sulphate which was in the plates when they were in their discharged condition, has been driven out of the plates by the electric charging current. The battery is then called charged.

I might say that in practice we **never let the battery discharge until it will give no more current. We find that if this is done, injury is done to the plates,** hence we always stop the discharge at a point which has been found safe. See "Over Discharging" further along.

Now a few words about charging. Only direct current can be used; never alternating current. When the power supply is A. C. it is necessary to change it to direct current for charging purposes. This may be done either by means of a motor generator set having a D. C. generator or by a rectifier.

In practice, we have found that we cannot charge at too high a rate. We can carry on the chemical action called charging no faster than the plates will respond. A high rate will do no good. On the contrary, it will heat up the battery plates and work injury to them. The charging rates to use are always given by the manufacturer. They must not be exceeded.

Now as to the actual construction of a commercial battery, such as is supplied to theatres for use with sound equipment.

Inasmuch as the amount of current which is obtained depends upon the amount of chemical action between the positive and negative plates immersed in the mixture of

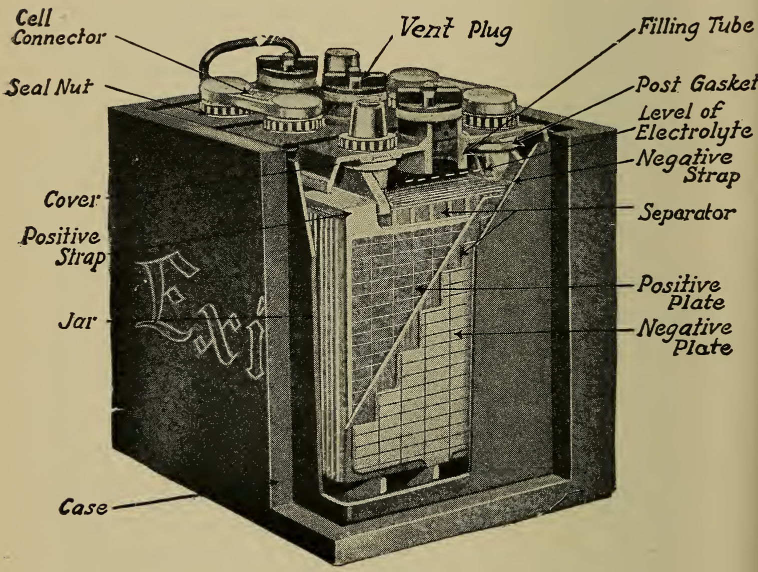


Figure 404.

Cut-away view of battery showing arrangement of plates and separators.

sulphuric acid and water, called the electrolyte, you will see that the more plates and the more electrolyte we have the greater will be the chemical action, and of course the more current we will be able to obtain. So we join together a number of positive plates and call it a positive group. We do the same for the negative plates. We now have available more plate surface, hence greater opportunity for chemical action. We therefore have a battery with greater capacity.

Of course it is necessary to insulate the positive plates from the negative plates when they are put together, as shown in Figs. 402 and 403, in the battery itself, or else we would have a short circuit and it would discharge internally. We do this by putting thin pieces of wood, called separators, between each positive and negative plate. Sometimes a perforated sheet of rubber is used in addition to the wood separator for additional insulation.

The positive and negative plate groups are assembled with the wood separators between the plates, the whole assembly put in a rubber jar, a rubber cover put on and the jar filled with a mixture of sulphuric acid and water, which is the electrolyte. The storage battery cell is then connected to a charging source and charged until the plates are converted chemically to lead peroxide for the positive and pure spongy lead for the negative. The storage battery cell is then ready for service.

Now, a word about specific gravity readings as taken with hydrometer syringe. There are very good reasons for taking these readings, because from them we can tell exactly what state of charge or discharge the battery is in. Here is the explanation:

Chemically pure sulphuric acid has a specific gravity of 1.835, water being taken as the standard, with a specific gravity of 1.000. Pure sulphuric acid therefore is almost twice as heavy as water. Electrolyte in a battery of the type you use is about 1.285 to 1.300 specific gravity. This specific gravity is obtained by mixing a pure acid of 1.835 specific gravity with water of 1.000 specific gravity in proportions set forth further along under "Electrolyte," the resultant mixture being about 1.285 to 1.300 specific gravity. You can see then that the sulphuric acid of the electrolyte of a battery is heavier than water. On discharge, the sulphuric acid in the electrolyte mixture leaves the electrolyte mixture to combine with the positive and negative plates of the battery. As the sulphuric acid was the heavy part of the electrolyte, the mixture will, on discharge, get more like water. That is, the specific gravity of the electrolyte will be lowered.

From specific gravity readings, therefore, we can tell just how much sulphuric acid has combined with the plates, and can therefore tell the extent to which the battery is discharged. Of course it follows that we can also tell when the battery is fully charged, because the specific gravity will not rise any higher, thus indicating that all of the sulphate has been driven out of the plates into the mixture.

If the directions and instructions herein contained are faithfully followed by the projectionist in charge, there will be little or no battery trouble. The batteries are well and ruggedly made. There is but little about them to cause trouble. **Battery trouble is almost invariably the result of carelessness or neglect in some form.**

You cannot mistreat or neglect storage batteries and get away with it. They will serve you well, provided you serve them well. If you do not, then they have a way of "getting back" at you, and they will do it, too. I emphasize this matter because of the fact that battery trouble is almost invariably the fault of the projectionist.

True, there is always the possibility of some individual cell having structural weakness, but under the rigid inspection and tests all parts are subjected to before being assembled in a battery, such cases are so very, very rare that they almost may be said to not exist.

Care of batteries is a simple matter, but it must be done thoroughly and well, and **must be done before trouble has a chance to start.** Once it has started—well, that is another story!

Moral: Do your duty by the batteries and they will do their duty by you.

BATTERY LOCATION.—In the process of charging, storage batteries give off hydrogen gas in considerable quantities. This gas is inflammable, and when mixed with air is explosive; also it is not healthful to breathe in quantity. It therefore follows that **batteries must be located in a well ventilated room—never in a confined place.** They must be so located that they will be readily accessible for examination and care.

As has been said, the battery gives off quantities of an explosive gas when charging. There may be more or less of this gas in the cells when they are not on charge. It therefore **is unsafe to have any open flame or spark, such as a candle, match, lantern, lighted cigar, cigaret or pipe near the batteries.** This is particularly true while the battery is on charge, or for half an hour thereafter.

The man who attempts to examine the water level of a cell, using a lighted match or other open light source, has no one but himself to blame if there is an explosion and he is badly burned or blinded for life.

If possible, have your batteries located on a table or shelf about the height of an ordinary table. If possible, have this shelf or table located where it is normally well lighted. Plenty of light and convenience in location makes for frequency and regularity of examination and care. **If the batteries are located in a dark, inconvenient place, they almost certainly will not have as excellent care as they would receive were the location convenient and well lighted.** That last is just plain common sense.

Never locate batteries and motor generators in the same room. The gases will corrode the wires if you do.

SPECIAL LIGHT SOURCE.—Even though the battery be located in a well lighted place, a light source will be needed to examine the water level in the cells. This may properly be (a) an incandescent lamp attached to a cord of sufficient length to permit of its use at each of the cells. This lamp should have a glass or porcelain opaque or semi-opaque shade to direct the light downward—glass or porcelain because a metallic shade would set up danger of short circuiting the cells by coming into contact with the connecting bars. It will be well to wind the lamp socket itself with insulating tape, or to use a porcelain socket. (b) A concentrated beam flashlight, with all its metal parts wound with insulating tape, so that if it be inadvertently laid down on top of a battery no harm will be done. This lamp should be attached, by means of a light chain run through a light rubber hose for insulating purposes, to some nearby stationary object. This is so that when the lamp is wanted it will be there. An incandescent lamp, as above described, is best, however, because a flashlight battery may be found to be dead just when the lamp is most needed, with consequent postponement of needed inspection or battery care.

CLEANLINESS.—It is said that cleanliness is next to Godliness. I don't know about that, but certainly cleanliness around storage batteries is next to good service by the batteries, and dampness and dirt is "next to trouble," and plenty of it.

The man who permits dust and dirt to accumulate on his battery tops, or who slops water on them in filling the cells, and permits it to remain there, is issuing an engraved invitation to Old Man Trouble to step in and sit down. He will, in all human probability, do it, too!

Keep the tops of your batteries scrupulously clean and dry. If in filling a cell you accidentally slop water on its top, wipe it off perfectly dry as soon as the filling is complete. **Examine the battery tops at a regular set time each week.** By that is meant that some certain day should be set apart as **"battery examination day."** Clean the battery exteriors thoroughly, particularly the tops. Draw a cloth under all connecting bars to remove accumulations of dust and moisture.

A dirty battery top speaks in eloquent terms of a sloppy, neglectful man in charge.

Accumulations of dust, dirt and (or) moisture on the battery tops will set up current leakage, which in turn sets up an effect in the amplifiers made manifest at the horns in the form of noise very similar to what is termed "surface noise." This is equally true of any and all systems of sound reproduction.

CLEANING SOLUTION.—A cloth dampened with ordinary household ammonia is excellent for cleaning battery tops, because not only is the ammonia cleansing, but also it serves to neutralize any battery acid (electrolyte) which may be there—droppings from tip of hydrometer syringe, etc. An equally efficient liquid having similar action is a solution of bicarbonate of soda (baking soda) and water in the proportion of a pound of soda to a gallon of water.

WARNING.—In using ammonia or soda, be careful that none gets into the battery. The action of both, as I have said, is to neutralize the acid, which would, of course, weaken the electrolyte in proportion to the amount entering. Don't wet your cleaning cloth sopping wet. Just dampen it well with the ammonia or soda solution, and you will have no trouble. After cleaning with ammonia or bicarbonate solution, wipe off the battery with clean water and wipe dry.

IMPORTANT.—Should electrolyte be spilled on the battery top, first having made certain that all filling plugs are tightly in place, wash it off with the ammonia or soda solution, wiping the top afterward with water, and then wipe perfectly dry when you have done.

ADDING WATER.—Observe Fig. 404. The maximum water level is just below the lower rim of the filling hole, as therein shown. As to battery water, there is a misunderstanding regarding it. It is a fact that water may be used from the water mains of many cities, even though the pipes be of iron. Croton water here in New York City is safe for battery use. The water in the Borough of Queens, however, is artesian water and is not fit for use in batteries. The water from your own water service **may** be safe, also **it may not be.**

Here is the rule: If you are in doubt about the water, write The Electric Storage Battery Service, Alleghany Avenue and Nineteenth Street, Philadelphia, Pa., and they will advise you definitely, asking for a quart sample of water for analysis if necessary. This should be checked up once a year thereafter.

The rule with regard to water is: **Use only distilled water in the batteries, unless your city or other water supply has been tested within one year and pronounced safe for battery use.** This may be supplemented by the statement that rain water from a shingle roof is always safe for battery use. In collecting this water, allow time for the roof to be washed clean and collect the water in glass or porcelain vessels.

The foregoing comes direct from the Electric Storage Battery Company (Exide) engineering department; therefore, is official. As I have said, water from iron pipes may be all right—also it may not. **It must not be used until analyzed at a laboratory and pronounced safe.**

Never permit the water level to drop below the tops of the plates. In glass jars fill to the water line. With rubber jars, fill to just below the lower end of the filling tube.

To allow the water to drop below the tops of the plates permits as much of the plates as are exposed to the air to dry out and thereafter that portion of the plate will have no chemical reaction, hence be dead. This will, of course, reduce the battery capacity exactly in proportion to the percentage of plate area exposed to the air.

Once rendered dead in this manner, the surface can only again be made active by an elaborate process at the factory, and since this would be prohibitive in cost, the effect is that the battery is permanently disabled. Moreover, there is a permanent deterioration of that portion of the plates which has dried and this will in time serve to kill the battery.

WHEN WATER SHOULD BE ADDED.—The best procedure is to add water just before you start to charge the battery. This by reason of the fact that then the water will become thoroughly mixed and incorporated with the electrolyte.

WARNING.—Never add water to a battery just before or during the running of a show. If you do, you may expect that the theatre horns will know, and let you and the audience know, too.

LET THEM STAND A WHILE.—Never use a battery immediately after charging. Let them stand for at least a full half hour. When a battery is under charge, the electrolyte bubbles and throws off gas. This continues in constantly lessening degree, but sufficiently to make itself manifest in the form of noise at the horns for a considerable while after charging has ceased. Only after the lapse of half an hour can you feel safe that it will have entirely ceased.

HYDROMETER READINGS. — The hydrometer reading you take is really a reading of the specific gravity of the electrolyte. Put in another way, it is a reading of the proportion or percentage of acid which has been removed from the electrolyte and incorporated in the plates themselves in the process of use. It is a reading of the relative strength or weakness of the electrolyte.

Hydrometer readings should always be carefully made. It is not merely a matter of dipping the syringe tip into the solution, sucking some of it up and glancing carelessly or hastily at the figures on the bulb.

To secure a correct, reliable reading you must, of course, suck up enough electrolyte to cause the bulb to float clear of the bottom and release all pressure on the rubber bulb. **Be careful,** however, not to suck up enough to cause the tip of the bulb to touch at the top.

If there is not sufficient electrolyte to enable you to suck up enough electrolyte to float the bulb, then add water, but **do not then take a reading** until after you have either used or charged the battery. A reading taken just after adding water would be worse than useless, because it would be deceiving. However, the careful projectionist will watch the water level and never permit it to get that low.

OVER-DISCHARGING.—Be very careful never to over-discharge a battery. That is to say, never permit a battery to run too low before re-charging. As has already been set forth, lead sulphate is formed on both the positive and negative plates while a battery is discharging—while it is working and producing power.

Lead sulphate occupies more space, or has greater volume than has either the lead peroxide of the positive or the pure lead of the negative plates. The makers of the battery will have made allowance for this condition in the construction of the plates, **but only on the assumption that the discharge will be kept within the limits set.**

If that limit be much exceeded and the battery thus run too low, sulphate will be formed in excess of the provision made and, having no other place to go, it will literally be forced into the battery plates, which will work permanent injury to them and shorten their lives.

Never permit your batteries to fall below the minimum hydrometer reading specified for your particular

batteries. Should you do so, the plates will receive permanent injury in proportion to the drop below the permissible minimum.

ELECTROLYTE.—The electrolyte is a solution of pure commercial sulphuric acid and approved water. "Approved" water is distilled water, water from a shingle roof, or water which has been tested and found free from impurities injurious to batteries. The proportions are thirteen and one-half (13.5) parts of acid to twelve hundred (1200) parts of water by weight, or twenty-five (25) parts of acid to one hundred and twenty (120) parts of water by volume.

The proportions are merely supplied you as a matter of information. **Do not attempt to mix your own electrolyte!** Instead, secure from the battery maker a bottle of electrolyte of the same specific gravity as that originally in the battery. Keep this on hand for use in case of accidental spilling of a part of the electrolyte from a cell. Should that happen, first charge the battery until there is no rise in specific gravity over a period of three (3) hours. Then add acid from your reserve stock until its level is just below the filling hole. **Never add acid except to replace electrolyte lost by spillage.**

Aside from acid being spilled, or through wastage by drippings from the hydrometer syringe, etcetera, the electrolyte strength never varies. It does **not** become weak with age. The water evaporates and the cells must be refilled every few days, but the acid therein contained remains intact.

BATTERY TERMINALS.—When a new battery reaches you, its terminals will be found to be coated with vaseline. This is to prevent corrosion. It should not be disturbed, except there be signs of deposit. If deposit appears, wipe off all vaseline. Disconnect the terminal. Scrape off all deposit, until the metal is clean and bright.

Next, having made sure the stud and interior of the clamp is clean, wipe it with a cloth dampened with ammonia or soda solution, grease stud and interior of clamping band with vaseline and bolt the two tightly together. Coat the whole terminal with vaseline and the job is done, **but test the clamp nuts once each week to be sure they are tight.** A terminal not perfectly tight makes itself manifest in the form of noise in the theatre horns. Sometimes these terminal connections loosen up, so go over them regularly and tighten them up if necessary.

The only man who can't be cheerful at his job is the undertaker.

The service engineer can't do it all! The projectionist must do his full part, too.

Western Electric Reproduction

ANY sound-on-the-film and the disc record method may use the Western Electric equipment, which is supplied and serviced by the Electric Research Products Company. Except for difference in what we may term "picking up the sound," the equipment for sound-on-the-film and disc reproduction is identical, hence one description will serve for both, insofar as has to do with amplifiers, horns, etcetera.

Referring to Fig. 383, each line therein shown, and the shadings between is very narrow, as you may see by examining the Movietone sound track itself. Yet if the sound reproduction is to be a true reproduction of the original sound combinations, each one of these thin lines must be illuminated individually and separately as it passes over the projector sound aperture. Not only that, but each sound modulation represented by the shadings between what we may call the "lines," must be given its exactly true value.

If parts of two adjacent lines be illuminated simultaneously, or if parts of two modulations be lighted at the same time, then the reproduction will not be good. There will be a sound blur in proportion to the amount of fault.

Think that over before proceeding further. It means that the line of light illuminating the sound band must be (a) a very narrow or "thin" line vertically; it must be (b) precisely at right angles with an imaginary line drawn lengthwise through the center of the sound track.

It must, of course, be in precise register throughout its length with the line of light which originally illuminated the sound track in the camera.

The foregoing is not only true of Movietone, but also it is true of all others using the variable density method of recording.

WESTERN ELECTRIC PICK-UP. — The photographic imprint of sound upon the variable density sound band has already been explained to you, see page 975. It is in the form of horizontal (horizontal as the film is in the projector) lines of varying width, made up or composed of photographic shadings, all of which, taken as a whole, is the photographic representation of sound, in all its combinations and modulations. It is illustrated in magnified form, in Figs. 383 and 384.

The problem in projection is to pick up those lines and shadings in the form of light, at their exact true valuation as expressed lineally upon the sound band, and to translate these light values into electrical impulses without distortion, to amplify them and finally to send them forth into theatre auditoriums in the form of sound which will be undistorted, have correct volume and be in every way a faithful reproduction of the sounds originally "heard" by the microphone.

We will now proceed to examine the Western Electric pick-up. The optical system of the sound pick-up attachment attached to the motion picture projector consists of a straight coil filament light source, contained in a glass globe, known as the "exciting lamp," a small condenser, a "slit," a small objective lens, the sound track upon the motion picture film and the photo-electric cell, the arrangement of which elements with relation to each other is diagrammatically illustrated in Fig. 405.

The condenser, the slit and the objective lens are all contained in a dust-tight metallic tube, or "barrel," which unit is commonly referred to as the "slit assembly." This assembly is located with great precision at the laboratory, a microscope being used for the purpose. It is

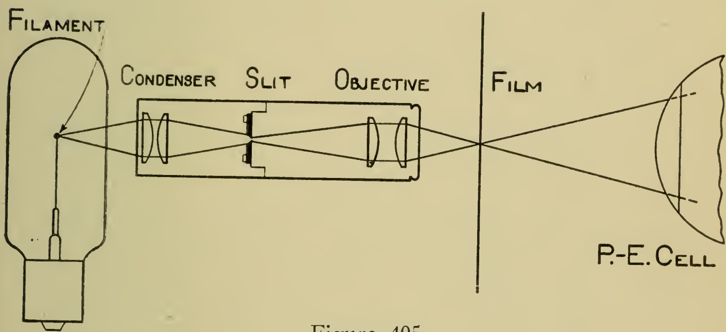


Figure 405.

sealed in that position, for reasons which will be later explained.

THE EXCITING LAMP.—The exciting lamp, sometimes called the "sound lamp," supplies illumination to the sound band. This illumination is steady. By that it is meant that the illumination of the sound band is at a fixed, steady value which does not vary.

In front of the sound lamp and at a fixed distance therefrom is a plano convex condenser very similar to those used with the straight arc in motion picture projection, except that instead of being 4½ inches in diameter this one is only about five-eighths (⅝) of an inch in diameter. Its purpose is to concentrate the light in a "spot" upon the "slit," just as the condenser concentrates the light in a spot at the projector aperture. In the side of the assembly cell is a small observation port, or window, through which the projectionist may observe the slit spot, and so adjust it that it centers upon and properly covers the slit.

THE SLIT.—What is known as the "slit" is just what its name implies. It is formed by two knife edges placed exactly parallel with each other, located one and one-half (1½) thousandths of an inch apart. As you will see by referring to Fig. 385, it is located approximately midway between the condenser and the objective lens of the slit assemblage. It, the slit, is three-sixteenths of an inch in length.

Now get the following clearly fixed in your mind: As has been related, the similar slit through which the sound band is illuminated at the camera was precisely at right angles with an imaginary line drawn lengthwise through the center of the sound track. That meant that as the sound track passed through this thin line of light, the varying densities of impression left upon the sound track by the light were in a horizontal plane and appeared after development in the form of lines exactly at right angles to the above mentioned imaginary line.

I think it will be obvious to you that what was impressed upon the sound track at the camera must be picked up in precisely the same way at the projector sound aperture.

All right! In order to pick up the photographic impressions exactly as they were impressed, it is obviously necessary that the pick-up line of light register precisely with the line of light which illuminated the sound track. Not only is that true, but also the speed at which the film traveled through the camera must be exactly duplicated in its speed through the projector, which is taken care of by the projector motor regulator (see "Motor Control Box," page 1127). The camera and projector speed is ninety feet of film per minute, or eighteen inches or twenty-four frames per second.

REASON FOR SEALING.—In order that the camera recording slit and the projector pick-up slit be precisely in register, and the slit precisely the right distance from the condenser and objective, and the whole assemblage at precisely the right distance from the sound band plane, the slit assemblage is microscopically adjusted and sealed in position. The necessary adjustment must be made with a specially constructed microscope. As the equipment is now designed, this adjustment cannot possibly be correctly made by the projectionist. Any necessary adjustment is a service engineer job. The projectionist must not disturb the seal under any conditions.

If you will consider the matter for a moment, you will see that if the camera slit is in proper position when the record is made, as we may assume it always will be, and the projector pick-up slit be rotated ever so little, then the two will not register, and since the camera slit does not register the same thing (unless the sound happens to remain at exactly the same value for a period of time) at any two points of the sound track length, even though separated by only one-thousandth of an inch, it follows that such rotation would cause a blur in the sound in proportion to the amount of the fault. Also if the sound assemblage barrel be displaced laterally ever so little, there would be injury done to both the volume and the quality of sound.

Moral: That seal was placed there for a most excellent reason. **Let it severely alone!**

I have set this forth at length for the reason that some projectionists have complained about the assemblage being sealed in place. They have the idea that they should be permitted to remove it for cleaning, et cetera.

As I have said, the assemblage is dustproof. Neither oil nor anything else can get into it and its replacement in perfect adjustment would be a practical impossibility for the projectionist. If the assemblage seems in need of attention, have the service engineer attend to it. **Under no conditions would the projectionist be warranted in breaking the seal.**

We have now examined the slit assemblage and have seen how it projects upon the sound band a thin line of light in exact horizontal register with the lines upon the band, so that only the individual line passing under the light is illuminated. Perhaps a more understandable way of putting it would be to say that as the sound band passes over the sound aperture, only a space upon it .080 of an inch wide by .001 of an inch thick, or "high," is illuminated, which is less than the actual dimensions of the slit, the reduction being accomplished by the slit projection lens and the .080-inch wide aperture in the aperture plate over which the film passes.

We will now go a step further and see what this is all about. We have seen that the sound band is illuminated by a line of light of the dimensions just set forth. We also know that this line of light has a steady, unvarying brilliance when it reaches the film.

On the other side of the film it, however, is very different. The line of light has passed through the sound band and, since the film is running steadily at the rate of ninety feet per minute, and since the photographic density of the sound band varies continually in proportion to the sound which caused its impression upon the band, it follows that on the side of the film we now are examining we shall have a beam of light which will vary constantly in brilliance, and will be an exact reproduction of the light beam from the camera slit which made the photographic impression through which it has passed.

The problem now is to transform these light variations back into electric variations the same as those which came from the receiving microphone and operated the Aeo lamp at the camera.

Examining Fig. 385 we find, on the extreme right, "P.-E. Cell," which stands for photo-electric cell, which is the device by means of which the light beam variations are transformed into electric vibrations of exactly equal values.

You will find the action of this cell set forth under "The Photo-Electric Cell" (see page 1013), which description coupled with what has been said completes the description of the Western Electric Pick-Up System.

What such systems do in recording and picking up is to receive sound vibrations traveling through the air, change them into electrical vibrations, again change them into light vibrations and photographically impress those vibrations upon the sound track of a film. It then again picks them up in the form of light vibrations, transforms them into electrical vibrations, amplifies them approximately 100,000,000 times and changes them back into an exact duplication of the original air vibrations which set the receiving or recording system into motion.

Don't neglect to learn all it is humanly possible to learn. Some day there will be a lot of money in the house and something will go wrong when the service engineer is a hundred miles away or busy at some other theatre. Then, unless you know what to do, you're sunk—and the money must be given back.

Western Electric Disc Record Pick-up System

IN order to grasp and understand the manner in which the Western Electric Company disc record sound pick-up operates, it is necessary to be aware of and understand one of the fundamental laws of electric and magnetic action upon which the action of the pick-up is based.

According to this fundamental law, if a coil of wire is wound around an iron bar (called a "core") which can be magnetized, whenever and as often as the magnetism in that core is in any degree altered or changed, **a voltage will be generated in the coil while the magnetism is changing,** which voltage will be in exact proportion to the amount or rate of change in strength of the magnetic field. No voltage will be generated so long as the magnetism remains steady, but only while a change in magnetic density is taking place. This is a principle with which many projectionists will be more or less familiar through having studied the action of transformers. It is the principle upon which disc record sound pick-up, as applies to Western Electric equipment, depends for its action.

HOW MAGNETISM IS ALTERED.—Given such a coil and core as is above described, one method by means of which the magnetism of the core may be changed is to place it "across" the terminals of a U-shaped (horse shoe) magnet, in such manner that each end of the core is close to, but not in contact with, one end of the U. When used thus the core is called an "armature," and most of the magnetism produced by the U passes through it, and, as you will readily understand, the closer the armature ends are to the U tips, the greater will be the amount of magnetic flow, and vice versa.

You are told on page 987 that in following the groove in a record the needle does not bob up and down through a series of indentations in the bottom of the groove, as many suppose, but that the sound is carried in the undulations of the sides of the record groove, which cause the needle to sway slightly from side to side.

The movement of the needle and the law above cited are the two things which make the Western Electric disc record pick-up possible, for such a coil and armature are located in a magnetic field, substantially as described, and the distance of the armature from the magnet poles is controlled by the movement of the needle as it travels through the groove-side undulations.

It therefore is not difficult to understand that as the needle moves the armature back and forth, E M F will be generated in the coil, which will exactly correspond to the groove undulations, and since those undulations correspond exactly to the sound waves which produced them, it follows that we will have E M F generated in the coil which will correspond in amount or power precisely to the sound waves. In other words, we will have the sound waves thus exactly reproduced in the form of electric voltage, or "current."

In considering this, gentlemen, you must try to realize the enormous rapidity of electrical action—a difficult thing for any but the engineer to do—and understand that while the movement of the armature will of necessity be very slight, it nevertheless will affect magnetic changes just as accurately as though it were measured in inches instead of thousandths of an inch.

This device is really, to give it its correct title, an Electro-Magnetic reproducer. The E M F it generates is almost too weak to understand, but, thanks to our modern methods of amplification, its strength may be multiplied until it will give almost any desired volume at the horns.

Of course the foregoing only sets forth the operating principle of the electro-magnetic pick-up. There are many details of construction which must be given very careful attention if a reproducer is to be built which will be reliable, sufficiently rugged to withstand such abuses as come to all equipment put out into actual operation and often placed in the hands of men who do not understand such things or their handling as well as they might, and which will, besides that, give satisfactory results at the horns in the matter of volume, tone quality and almost immeasurably minute variations which go to make up, for example, an orchestral performance.

In this device the magnet pole pieces are especially designed to concentrate the magnetic force upon the tiny armature in just the right way. The pivot connected with the magnet armature and the reproducer diaphragm is and must be so designed that there is absolutely no lost motion, and at the same time no binding. However, it is necessary that there be a certain amount of stiffness or friction to prevent any unnecessary wobbling.

In its original design the Western Electric reproducer, the construction was substantially as we have described.

The armature was a piece of soft iron laminated (built up of thin plates) about one inch in length by one-twenty-fourth of an inch in thickness. Its center was pivoted. It was surrounded by a coil. The magnet pole pieces also were laminated. Lamination improves efficiency in operation.

The armature pivot is of the "knife edge" type employed in the construction of fine scales and other precision instruments. It is a type of bearing which reduces "lost motion" to practically nothing at all. The armature is held in place on the pivot by means of a spring, thus providing the stiffness or friction required to prevent unnecessary wabbling, and at the same time eliminating all lost motion.

PRESENT DESIGN.—The present design of Western Electric disc record reproducer is somewhat different from that described. For one thing it is oil damped, which means the entire mechanism of the reproducer is enclosed in a casing filled with oil. This is an excellent method of dampening or smoothing out any tendency to excessive freedom of movement, or "wobble," on the part of the needle.

In the side of the case opposite the magnetic poles, is a thin, steel diaphragm, to which the needle holder is attached. The flexibility of this diaphragm permits the needle sufficient freedom to follow the record groove undulations. It also serves as the armature concerning the action of which we have talked. One of the magnet pole-pieces is in the form of a circle. It extends around the edge of the steel diaphragm. The other magnet pole-piece is double, and is located opposite the center of the diaphragm, its end a few thousandths of an inch removed from the diaphragm. It has a coil wound upon each of its prongs, which are both of the same polarity.

You will thus see that the arrangement would amount, insofar as concerns magnetic action, to essentially the same thing as would a straight armature across the legs of a U magnet, but that it provides a far better mechanical arrangement for our purpose. The movements of the needle caused by the record groove undulations will of course be exactly reproduced in the flexing (bending) of the diaphragm, the greatest effect of which will be concentrated at its center, and since the center pole-piece is placed at a certain fixed distance from the center of the diaphragm when it is at rest, it follows that the needle movements will be precisely reproduced in alterations of distance between the diaphragm center and end of center pole-piece, and therefore in alterations of E M F generated in the coil.

NO TAMPERING PERMITTED.—Such reproducers as I have described require very delicate adjustment. The clearance between the armature or diaphragm and the center pole-piece is but a few thousandths of an inch. The projectionist is not equipped to make such delicate adjustments. He is warned to not tamper with reproducer adjustments, but use the spare provided and deliver any reproducer he believes to be defective to the Service Engineer. **Never, under any circumstances, open the case of an oil damped reproducer!** If you do, you risk having a new one delivered and the cost of the one you have opened charged to your theatre.

Noise doesn't get you much or anywhere. The rooster can crow but when you look for the egg, it is not there. Be a doer, not a crower.

The Fader

THE fader used in connection with Western Electric sound reproduction equipment, is nothing more or less than a fixed resistance connected in series with the motion picture projector film pick-up amplifier, in combination with a variable connection between this resist-

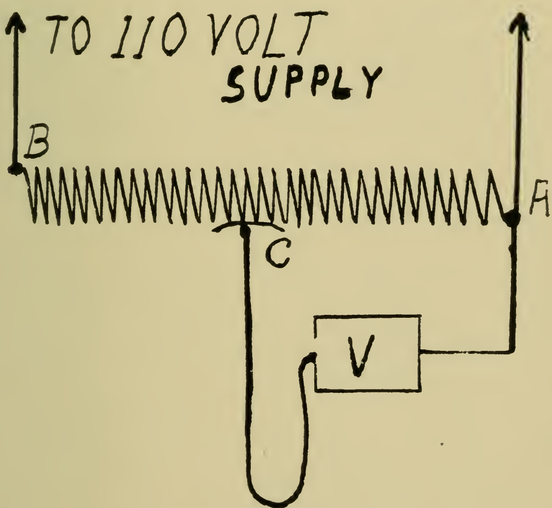


Figure 406.

ance and the main amplifying panel. It is the device by means of which the projectionist is enabled to control the volume of sound from nothing to the maximum value obtainable.

To understand the action of the circuit shown in Fig. 406 we must first consider the arrangement. We have here fixed resistance A B connected across a 110-volt supply circuit. There is also a voltmeter, V, one terminal of which connects to resistance at A; the other to sliding contact C.

Suppose we now move C along A B until it arrives at B. We then have for all practical purposes connected V directly across the 110-volt circuit. It will therefore register 110 volts. Suppose, however, we set C in the center of A B; in other words, midway between A B. We then would get a reading of $110 \div 2 = 55$ volts, since at that point (the middle half) the original supply voltage (110) has been used up in forcing the current through the resistance of A. Similarly by making a connection one-third the distance from A, the voltmeter would read $110 \div 3 = 36\frac{2}{3}$ volts. If the connection made one-tenth of the way from A, the reading would be $110 \div 10 = 11$ volts.

Obviously, then, by moving C back and forth along resistance A we may alter the voltage applied to V through the entire range, from 110 volts down to zero. In other words, we can vary the power available at V from zero to maximum.

Now if for the 110-volt supply indicated in Fig. 406 we substitute the terminals of the motion picture projector film pick-up amplifier circuit, and if in place of voltmeter V we have the input terminals of the main amplifier, it is evident that by altering the position of C we will be able to supply to the main amplifier with all or with any fraction we may please of the power available from the pick-up, and naturally the volume obtained from the horns will be in exact proportion to the power

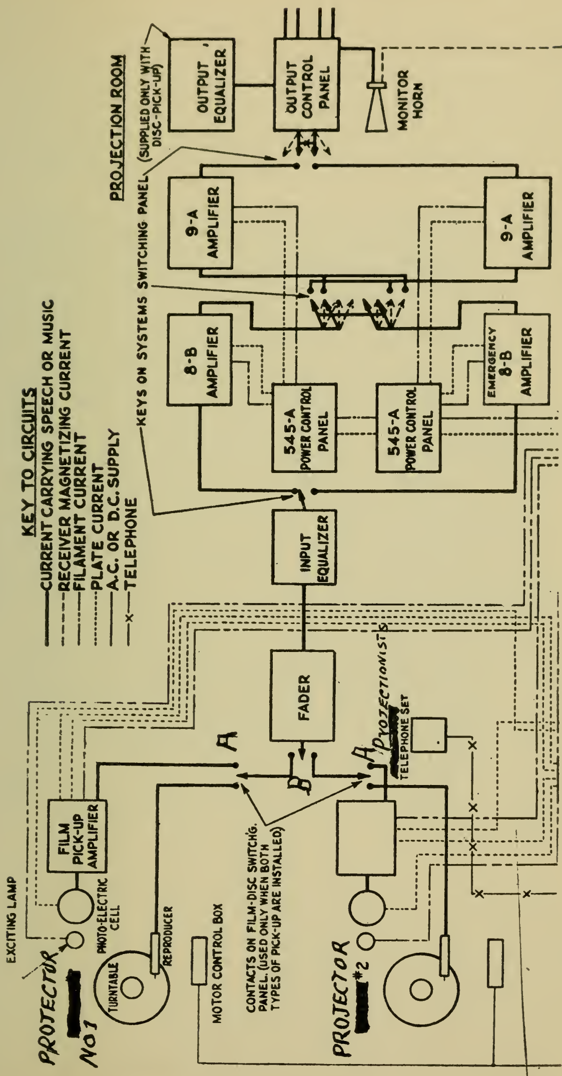

KEY TO CIRCUITS
CURRENT CARRYING SPEECH OR MUSIC
RECEIVER MAGNETIZING CURRENT
FILAMENT CURRENT
PLATE CURRENT
A.C. OR D.C. SUPPLY
TELEPHONE
PROJECTION ROOM
(SUPPLIED ONLY WITH DISC-PICK-UP)
OUTPUT EQUALIZER
OUTPUT CONTROL PANEL
MONITOR HORN
SWITCHING PANEL
9-A AMPLIFIER
9-A AMPLIFIER
KEYS ON SYSTEMS SWITCHING PANEL
8-B AMPLIFIER
EMERGENCY 8-B AMPLIFIER
545-A POWER CONTROL PANEL
545-A POWER CONTROL PANEL
INPUT EQUALIZER
FADER
PROJECTIONISTS TELEPHONE SET
A
B
A
FILM PICK-UP AMPLIFIER
EXCITING LAMP
PHOTO-ELECTRIC CELL
REPRODUCER
TURNTABLE
MOTOR CONTROL BOX
CONTACTS ON FILM-DISC SWITCHG. PANEL. (USED ONLY WHEN BOTH TYPES OF PICK-UP ARE INSTALLED)
PROJECTOR
PROJECTOR #2

Figure 407.

applied to the main amplifiers by the pick-up amplifiers.

That, gentlemen, fully explains the principle upon which the fader operates, though of course Fig. 406 does not illustrate the actual mechanical means by which the fader operates. That will be explained further on.

Some may wonder why a variable resistance in series between the pick-up amplifier and the main amplifier could not be used. In other words, a resistance connecting at B, but not at A. The answer is that the resistance would have to be enormously great in order to bring the power anywhere near zero, whereas by the arrangement shown in Fig. 406, all that is necessary is to bring C to A to stop all current flow in the main amplifier circuit. Moreover, it is a law in the design of electrical equipment of this kind, that as a general rule it works best when connected to a resistance or load similar to its own internal characteristics.

A, being a fixed resistance insofar as has to do with the pick-up amplifier, meets this requirement, which a variable resistance could not be made to do.

Examining Fig. 407 we see what the general set-up is. Tracing the heavy, black lines, which represent the circuits carrying sound current (Important: Each heavy black line represents a 2-wire circuit. Remember that fact or you may become confused), you will observe that the fader is located between the motion picture projector film pick-up amplifier (the first stage of amplification) and the main amplifiers. At A are the switches used to change from film to disc, or vice versa, where combination pick-up equipment is used. These switches are located on the upper part of the fader panel.

B, Fig. 407, indicates the switch with which the change is made from projector No. 1 to projector No. 2, or vice versa. If you remember that only the heavy black lines are to be considered in this matter, and that each such line represents a 2-wire circuit, I believe you should have no difficulty in understanding the diagram.

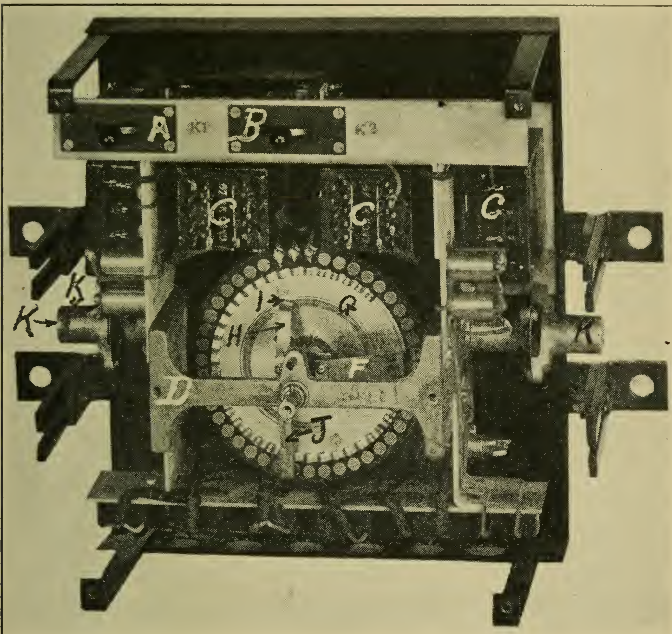


Figure 408.

Fader with Cover Removed.

A—Fader cut-out switch. B—Cut-out switch. C C C—Indicate parts which have no bearing upon the fader action. They are not in faders of latest types. D—Castiron frame which supplies a holding bearing for fader knob and parts which it operates. G—A metal disc electrically connected to one side of the circuit, the other side of which is connected to the round contacts surrounding the disc, to each of which a small resistance coil connects. H—Contact arm connecting with disc G through sliding contact L and with arm J which makes sliding contact with contact discs surrounding metal disc G. K K connection for rod extending from fader at one projector to fader at the other one.

Of course a resistance coil and slider such as is shown in Fig. 406 is not really used. Such an arrangement, while convenient for the purpose of illustrating the operating principle, would be a very poor mechanical device for practical use. In practice the same thing is accomplished in a very much better way by arranging thirty (30) short coils of resistance wire in a circle around a metal disc (G), which represents one side of the circuit, as shown in Fig. 408.

Half of these coils are connected in series with each other and in series with the upper circuit at B, Fig. 407, and half connected in series with each other and in series with the lower circuit at B, Fig. 407. In other words, half of them, fifteen in number, are connected in series with the film pick-up amplifier of each motion picture projector.

Examining Fig. 408, plate or disc G is connected to one side of the projector pick-up amplifier circuit. It therefore is charged by that circuit with its full voltage. The row of round contact buttons surrounding this disc rest on top of and each one is connected to one of the small resistance coils which, taken as a whole, represent resistance A B, Fig. 406. Arm J receives the current from disc G through sliding contact I, whence it passes through arms H and J to the resistance coil contact, the amount of resistance in series with the pick-up circuit at the moment being dependent upon the position of arm J. Arms H and J correspond and act exactly as would slider C, Fig. 406, insofar as electrical effect be concerned.

I think the action should be at least fairly plain to you. Arm F is nothing more than a locating arm. On its under surface, at its end, is a roller which is held

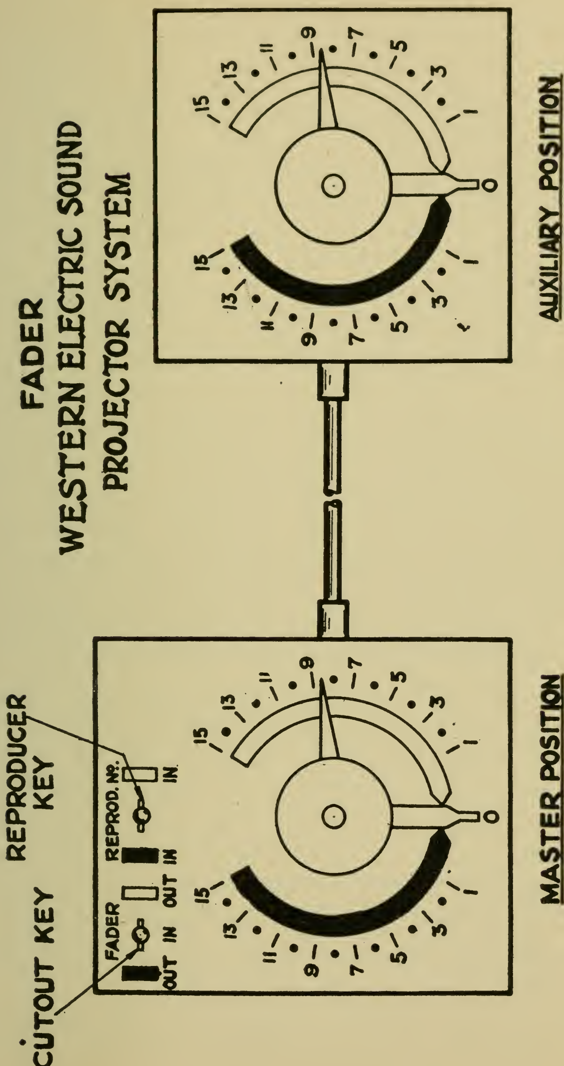

FADER
WESTERN ELECTRIC SOUND
PROJECTOR SYSTEM
CUTOUT KEY
REPRODUCER
KEY
FADER
REPROD. No.
OUT IN OUT IN
IN
MASTER POSITION
AUXILIARY POSITION

Figure 409.

down upon disc G with some pressure. As arm J is moved by the fader knob, this roller is made to travel along over the indentations you will observe in the edge of disc G, which same acts as a locating semi-lock to hold the arm in any desired position.

Switch A, Fig. 408, is to cut out the fader in case of trouble in it, and B is for use when three sound projectors are equipped for sound. The position of the fader as shown in Fig. 408 is zero. In other words, arm J is at the dividing line between the resistance coils connected with projectors No. 1 and No. 2.

Fig. 409 gives us a view of the face of the fader. Observe the black half circle and the corresponding white one on the other side. The black really is red but the white is white. The red side is in use when projector No. 1 (the left-hand projector) is running. The white side is for the other projector. The change is made merely by moving the pointer over by means of the fader operating knob. There are two fader heads in each installation, but they are connected so that when you turn the knob of either it operates the knob of the other. One head is merely a "dummy." It has no resistance. It is merely to permit the real fader being operated conveniently from operating position at either projector. The "dummy" is "auxiliary position," Fig. 409.

The numbers range, as you see, from one (1) to fifteen (15), each number corresponding to one resistance coil, so that when you retard or advance the pointer by one number you have cut in or cut out one of the resistance coils.

The ordinary operating position is usually somewhere around nine (9). Moving the pointer to higher numbers increases the volume of sound. Moving it to lower numbers of course decreases it. When the fader pointer is at zero there is no sound at all.

Always keep the pointer on one of the numbers, never between two of them. If it be between two numbers, then the contact shoe will rest on two contact buttons and there may be arcing, which will set up noise at the horns.

Either the red or the white side of the fader may be cut out of the circuit by throwing the switch marked "fader", located at the top of the fader casing to the side marked with the color in question.

FADER CAUTION.—Should it be found that after having started projection there is either no sound at all, or very poor sound, and investigation discloses the fact that you have (a) failed to light the exciting lamp or (b) close the sound gate, **do not either light the exciting lamp or close the sound gate until you have first retarded the fader to zero.** If you neglect to retard the fader to zero before closing the sound gate or lighting the exciting lamp, you may expect a blast of sound from the horns which will be altogether unpleasant.

When you have retarded the fader to zero and remedied the fault, then do not swing the fader quickly up to regular operating position, but advance it gradually.

The fader must always be at zero when projection starts, and only advanced **gradually** to regular operating position when the projector has attained normal speed.

Note: By "gradual" it is not meant that the action be excessively slow. You will very quickly come to understand how fast it may be advanced without causing an unpleasant effect, and that should be the speed of action. Just use your own good judgment, avoiding sound distortion and bringing the sound volume up as quickly as you can without it.

The proper method of handling the fader at change-over.—There is a right and a wrong way to do everything, including handling the fader, particularly at change-over. Just at that time several things are demanding attention at practically one and the same time, and unless you make it your habit to handle the fader in one certain way, you are likely to make an embarrassing mistake. The proper procedure is as follows: At the cue, start the projector motor, place your left hand on the douser and your right on the fader knob, making it your invariable habit to **grasp the fader knob exactly as shown in Fig. 410.**

This latter is of the utmost importance. It is an insurance against inadvertently moving the fader knob the wrong way, as may and does sometimes happen when this practice is not followed. An error in this respect results in increasing the sound just at the time it should be decreased, on the projector you are closing down, and if you are making the change close to the end of the film, it, the film, may run out before you can get the fader over to the other side. This will of course cause a serious "balk" in the sound, besides an unpleasant roar of sound when you raise the volume instead of decreasing it. It is very bad in any event.

However, if you form the habit of grasping the fader as shown at fade-over time, it will never occur, because, as you will see, it would be very difficult to turn the knob the wrong way when grasped as shown. The movement is in the direction of the arrows.

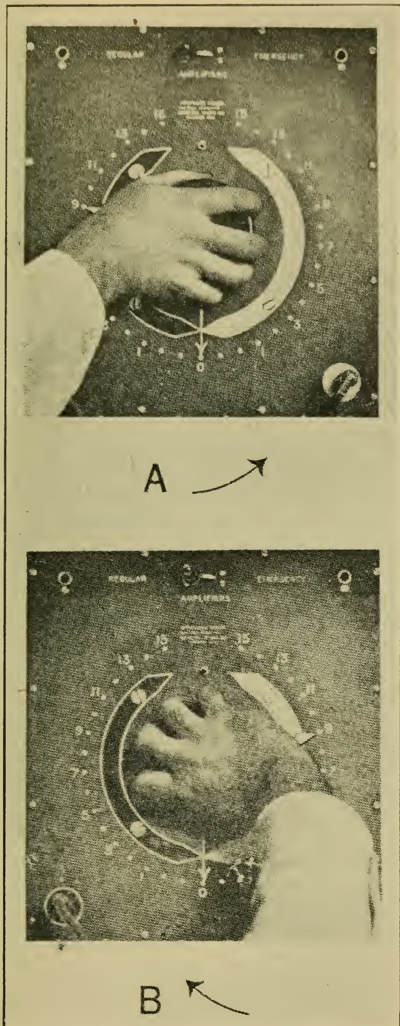


Figure 410.

Is your projector optical system working at maximum efficiency, or is it wasting light?

Western Electric Motor Control Box

IT is essential to perfect reproduction of sound that the projector be driven at precisely the same speed that the taking mechanism was driven. Any variation as between the speed of taking and the speed of reproduction automatically results in altering the sound reproduction, which then is not a duplication of the original sound.

Any difference as between recording and reproduction speed sets up or produces distortion of the sound, which will be particularly noticeable in either music or voice. You may easily illustrate this by altering the speed of the turntable of your own home phonograph while playing any good record of music or voice.

Western Electric equipment is made to handle film on which the picture and sound record is made at the speed of ninety (90) feet per minute, or eighteen (18) inches per second. The driving gear is of such ratio that the driving motor must run exactly 1200 R. P. M. Understand clearly that the speed of ninety feet per minute must be constant. There can be but very little variation permitted, because speed changes will be instantly noticeable in the alteration of pitch in sound.

Should there be speed variations, and those variations be frequent, then the music would seem to be out of tune and the voice of singers or speakers more or less "shaky." However, whatever plan be adopted to regulate and stabilize the projection speed for sound, there must be provision for suitable alteration in speed when silent pictures are shown.

The Motor Control Box, in conjunction with the special motor employed to drive motion picture projectors where Western Electric sound apparatus is used, is designed to and does take care of the requirements above set forth, it having been decided that neither compound wound or synchronous motors would provide sufficiently close regulation of speed under the common voltage fluctuations and frequency fluctuations found in commercial power circuits supplying theatres. Lack of strong starting torque of synchronous motors was another objection.

The Motor Control Box depends for its operation upon what is known as a "tuned circuit," also called a "resonant circuit." In layman language this means a circuit which will permit the free passage of alternating current of a certain frequency, but will offer high resistance to current of any other frequency. The frequency such a circuit will pass is called a "resonant," a "tuned" or a "critical" frequency.

A simple demonstration of this phenomenon may be made as follows: cut an ordinary rubber band, such as we use to hold papers together, in two and, holding one end, attach a weight sufficient to stretch it somewhat to the other end. It will be found that if the weight be started bobbing up and down, so long as the movement is regularly timed, it will require slight effort on your part to maintain the regular up and down action of the weight. If, however, you alter the speed in any degree, you will discover that you have upset the rhythm, and

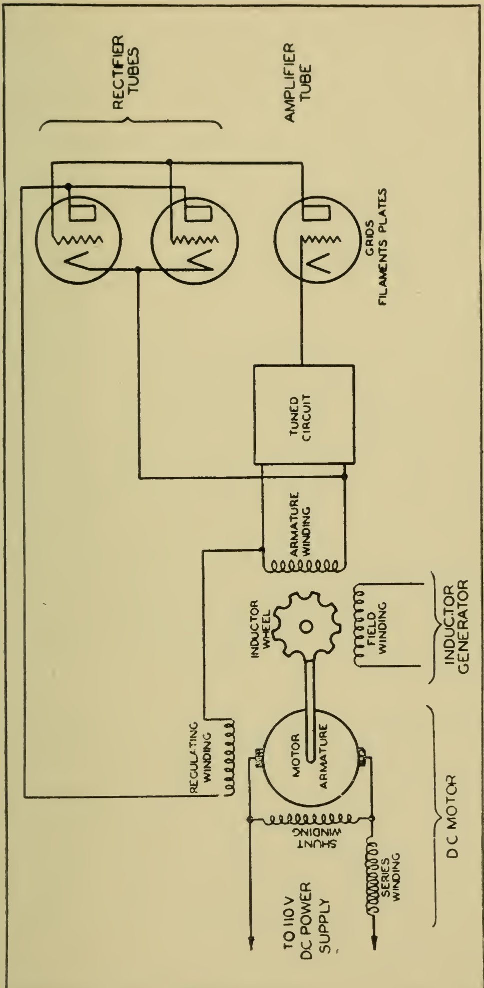

RECTIFIER TUBES
AMPLIFIER TUBE
GRIDS
FILAMENTS PLATES
TUNED CIRCUIT
ARMATURE WINDING
INDUCTOR WHEEL
FIELD WINDING
INDUCTOR GENERATOR
REGULATING WINDING
MOTOR ARMATURE
SHUNT WINDING
SERIES WINDING
D C MOTOR
TO 110 V DC POWER SUPPLY

Figure 411.

the rubber will give slight aid in bobbing the weight until you again settle to the former rate of speed.

In other words the mechanical arrangement is such that it will permit of back-and-forth movement at a certain sustained rate of frequency, but will offer resistance to other frequencies, which is analogous to the action of a tuned electrical circuit. It is also very similar to the action of a tuning fork, which will vibrate only at the speed it was designed to act at. In fact, any combination of mass and elasticity will act much the same way.

And now we arrive at the meat of this particular nut. A choke coil or an inductance has the same effect upon an alternating circuit that a weight has upon a rubber band, or as a flywheel has upon a mechanical movement, and a condenser (See page 1017) plays the same part electrically that our rubber band does mechanically.

Alternating current is nothing but a back-and-forth movement of electricity in a circuit, hence by the use of a choke coil and a condenser it is possible to set up or create resonance effects. Basically that is all there is to a "tuned circuit."

In stabilizing motor speed the first requirement is that the motor must automatically "advise" the control box of any variation in its speed. This has, in this case, been effectually accomplished by building into the motor a small A. C. generator, located on the motor armature shaft and covered by the same housing. Figs. 411 and 412 show the plan applied to both an A. C. and a D. C. motor, in simplified form.

This small generator will generate A. C. whenever the projector driving motor is in operation, and the fre-

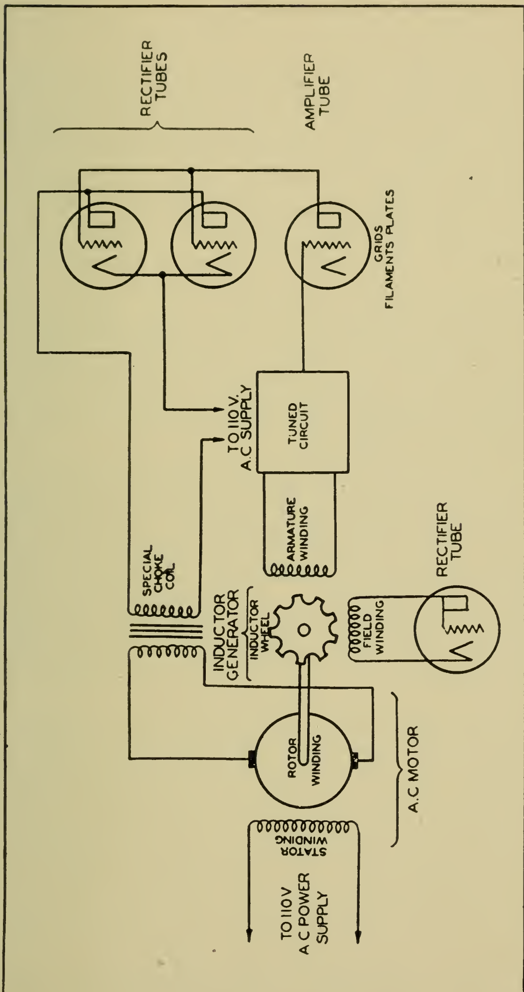

RECTIFIER TUBES
AMPLIFIER TUBE
GRIDS
FILAMENTS
PLATES
TO 110V. A.C SUPPLY
TUNED CIRCUIT
ARMATURE WINDING
SPECIAL CHOKE COIL
INDUCTOR GENERATOR
INDUCTOR WHEEL
FIELD WINDING
RECTIFIER TUBE
ROTOR WINDING
A.C MOTOR
STATOR WINDING
TO 110V A C POWER SUPPLY

Figure 412.

quency of the current so produced will of course always be exactly proportional to the speed of the motor at the time.

When the motor is running at the standard speed of 1200 R. P. M., which drives the projector at the rate of ninety feet of film per minute, the small generator is producing A. C. at a frequency of 720 cycles per second. Of course at a less speed than 1200 the frequency would be less than 720 and above 1200 it would be greater than 720.

The critical frequency of the tuned circuit of the motor control box is 720 cycles. By this it is meant that it will pass A. C. of that frequency, but will not pass it at any other frequency, which is the key to the action of this particular apparatus.

When you first start the motor the generator frequency will of course be below 720, hence no current can pass through the tuned circuit and the motor will pick up speed in the usual manner. However, when a speed of 1200 R. P. M. is reached, then current passes through the tuned circuit, and this so affects the control circuit of the motor that there will be no further increase in speed.

And now to take up the action in greater detail. The motor used on D. C. supply is a compound wound motor of the regular type, except that in addition to the usual shunt and series windings it has a special speed regulating winding, the current for which is supplied from the motor control box. The speed of a D. C. motor is increased when the field current is weakened and decreased when it is strengthened, which fact is taken advantage of as the means for regulating the speed of the motor. The field winding for the pilot generator is supplied with current from the mains. In the D. C.

control box are three vacuum tubes. Two of these act as rectifier tubes, changing the pilot generator current to D. C. for supplying the regulating field on the motor. The amount of current these tubes will pass, however, depends on their grid bias, which is controlled by the third tube, which in turn is operated as an amplifier by the tuned circuit. At speeds below 1200 R. P. M. the grids of the rectified tubes are negatively biased, therefore the rectified current through the motor regulating field is small, permitting it to speed up. At 1200 R. P. M., the tuned circuit functions and the negative grid bias of the rectified tubes is decreased, causing the regulating field to strengthen so that no further rise in speed can take place. If the speed tends to go above 1200 R. P. M., this effect becomes still more pronounced.

The motor control box circuit functions in this manner when the regulating switch is in the "Reg" position. When it is in the "Var" position, the tuned circuit and vacuum tubes do not function; the regulating field winding is supplied with D. C. from the mains through a rheostat connected with the control knob, which therefore regulates the speed as desired when it is turned.

The motor used on A. C. supply is of the repulsion type. Such motors have two windings, the stator winding, which is fixed and receives power from the mains, and the rotor winding, which is on the revolving part of the motor and is not connected to the power supply. This winding is connected to a commutator which has two brushes. If these brushes be connected through a circuit so that current can flow from one to the other, then the speed of the motor will depend on the amount of this current, hence by regulating the latter we can regulate the speed of the motor.

The A. C. motor control box, Fig. 412, contains four vacuum tubes. Of these, one is used to supply rectified current for the field of the pilot alternator. Two more tubes act as rectifiers, supplying current to one winding of a special choke coil. This coil has a second winding placed in the circuit which connects the motor brushes. When the current through the first winding is large the choking action of this coil is not very pronounced; therefore a relatively large rotor current can pass and the motor can speed up. As the current through the first winding is decreased, the choking action of the coil is increased, hence the motor speed is retarded. It then follows that the motor speed can be controlled by regulating the output of the rectifier tubes.

The output of the rectifier tubes depends on the bias supplied to the grids and this, in turn, is controlled by the fourth vacuum tube which is operated as an amplifier by the tuned circuit. At speeds below 1200 R. P. M. the grids of the two rectifier tubes have very little negative bias. These tubes therefore pass a relatively large current through the first winding of the choke coil, therefore a large rotor current circulates, allowing the motor to speed up. At 1200 R. P. M. the tuned circuit functions, causing the negative bias of the rectifier tubes to be increased, which decreases their output and therefore causes the choke coil to cut down the rotor current so that no further speed increase can take place. If the speed tends to go above 1200 R. P. M., this effect becomes still more pronounced.

The A. C. motor control box circuit functions in this manner when the regulating switch is in the "Reg" position. When it is in the "Var" position the tuned circuit is opened and does not function; the vacuum tubes continue in action, however, and the fourth or amplifier tube instead of being operated from the tuned circuit, is controlled by means of a resistance connected to the control knob, which therefore regulates the speed as desired when it is turned.

Further refinements are introduced into the motor control box circuits to sharpen the speed regulation and eliminate any tendency to momentary unsteadiness of speed, but these do not affect the main principles which have just been outlined.

Study! It's the most valuable thing you can do for yourself. Be able to talk to friend manager about sound and sound equipment intelligently. You can't bluff through. Unless you do know, friend manager will be wise to that fact before you've spilled two dozen words.

RCA Photophone Pick-up

THE RCA Photophone sound pick-up system includes (a) an exciting lamp; (b) a condenser lens approximately one inch in diameter; (c) a slit; (d) a small objective lens; (e) a sound gate and aperture, and (f) a photo-electric cell, all mounted in a metallic casing which may be had shaped for attachment to any of the present makes of professional motion picture projectors.

The exciting lamp is contained in a separate compartment of the said attachment. Its interior is shown photographically in Fig. 413.

In the exciting lamp compartment is a rotating base or table, the action of which is controlled by hand wheel D, Fig. 413. Mounted on the rotating table or base are three lamp sockets, in each of which it is designed that a lamp will be kept mounted, ready for instant use, so that in case an exciting lamp fails during the running of a show, it is only necessary to move hand wheel (D) one-third of a turn to bring another pre-adjusted lamp into use.

Electric contact for the lamp is provided as follows: Examining Fig. 413 you will see a wire, X, at the right. This is one of the wires of the electric circuit supplying current for the exciting lamp, the other wire being hidden from view. Looking closely you will see two bars of copper alloy, C and C′, to which the circuit wires are connected through the side of the compartment housing, being of course insulated from the metal thereof. At A you will see a flat copper contact attached to the edge of the rotating table, but insulated therefrom. At B you will see a contact screw. There are two of these for each lamp. They represent the terminals of the lamp filaments. When the base is rotated one-third of a tune, the two you see (A and B) will be brought into electrical contact with the two flat, current carrying "springs" C and C′, which automatically completes the circuit of the lamp. The sharp point of contact screw B slips into an indentation in contact bar C′ when the lamp is in operating position, which acts to locate the lamp in exactly the correct position.

These lamps are so made, and their sockets so placed that when the lamp is in the socket, its filament will, without further attention, be "square" with the slit. In other words, the filament will be exactly at right angles to the optical axis of the slit optical system contained in slit assembly barrel Z, Fig. 413.

We feel bound, in fairness, to say this is a very clever and effective arrangement for having spare exciting lamps always ready for instant replacement of any lamp which may fail.

The exciting lamp itself is a small incandescent globe having a coiled filament of small diameter held or supported in horizontal position. Such lamps and their filaments may be examined in Fig. 394. It is absolutely essential to good work that the exciting lamp filament be and remain in an exactly straight, exactly horizontal line. In this connection, examine and study the matter on pages 1057 to 1066.

WARNING.—Do not neglect to read and understand the matter contained in the above reference. **A sagged or warped exciting lamp filament will not only decrease**

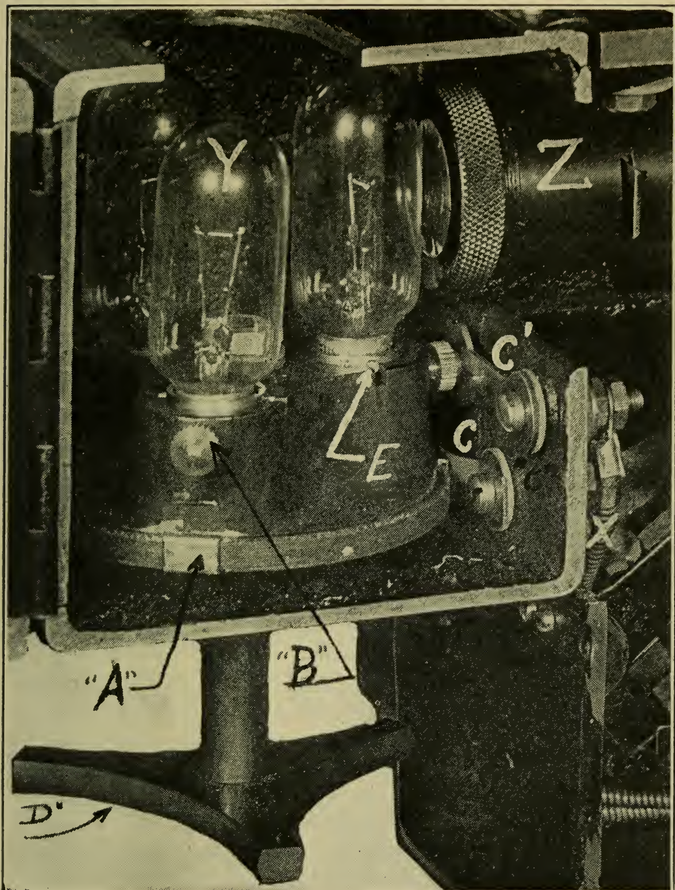


Figure 413.
RCA Photophone Exciting Lamp Compartment.

sound volume, but also it will tend to injure the tonal quality of the sound. However, at the risk of being accused of repeating, I will add that this is because of the fact that the filament illuminates a narrow slit, and since the most powerful illumination will be in a line representing the center of the filament, it follows that should the filament not be perfectly straight, the line representing the highest illumination value would not all fall upon the entire length of the slit, which is itself only .006 of an inch high. I think you will get the idea.

Summed up it amounts to this: you need the very best possible illumination at the slit opening, and upon every part of it, and you cannot possibly have it unless the exciting lamp filament be perfectly straight. **Examine the exciting lamp filament every day, discarding any lamp immediately its filament departs in any degree from a perfectly straight line.** See Fig. 394.

Clean the outer surface of the exciting lamp every day, just as you would clean a lens. A dusty, dirty globe will decrease the amount of light, and will to some extent tend to diffuse the light which does pass through the glass, all of which makes for general inefficiency and poor sound volume and quality.

BLACKENED GLOBE.—In course of time the interior of an exciting lamp globe will begin to darken. See Fig. 394. This is because of a deposit of matter thrown off by the filament. **Discard the lamp as soon as this condition appears.** True the lamp may be made to serve longer, but only at the sacrifice of both volume and sound quality. **It will be much cheaper to install a new lamp than to get a little more service from the old one at the expense of sound quality and volume.**

LOCATING THE EXCITING LAMP.—When it is necessary to replace an old exciting lamp with a new one, it is only necessary to give the rotating base a one-third rotary movement. This brings a new lamp into use and you should at once remove the old lamp from its socket, insert a new one and adjust it up and down until the light is properly adjusted upon the slit, and is right at the sound gate aperture, all of which may be judged by opening the sound gate and permitting the light beam to fall upon a white paper, such as a business card, which is held over the aperture, raising or lowering the lamp until the light upon the card is entirely even and free from shadows.

No attention need be paid to the distance of the lamp filament from the condenser, or to its being "square" with the slit, those things being taken care of by the way the apparatus is made, as follows: It is of course essential, as has already been explained, that the filament be at exactly right angles with the optical axis of the slit optical assembly.

This is accomplished in a very simple way. The exact position of the lamp in its socket is determined by a locating pin, E, Fig. 413, except that an up and down adjustment may be found necessary. The socket itself is so located upon the table that all socket slots are in precisely the same circumferential position.

In making the lamp, locating pin E, Fig. 413, is placed in the precise position which will bring the filament in its correct location with relation to the optical axis of the system when the lamp is put into a socket, **except** that it may be too high or too low, in which case it must be raised or lowered, as already set forth.

It therefore follows that with this apparatus the replacement of a sound lamp presents very little difficulty, and the change from one lamp to another may be accomplished almost instantly, should a lamp burn out during the projection of a reel of sound film.

THE OPTICAL SYSTEM.—In Fig. 414 we have a view of the RCA sound gate compartment and a Simplex projector mechanism below the intermittent sprocket, all compartment doors being removed. The relation of the sound gate compartment to the exciting lamp compartment is shown in this figure. In it you also will be able to trace the path of the film through the projector mechanism and sound compartment of RCA sound attachment and the standard Simplex mechanism.

Barrel A contains the condenser, the slit and the tiny objective lens. The action is as follows: The condenser is composed of two plano convex lenses about one inch in diameter, their convex surfaces facing each other, the apex of the surfaces separated by the small fraction of an inch.

These lenses concentrate the light from the exciting lamp filament upon the "slit," which is an opening located in horizontal position, .510 of an inch wide by .006 of an inch high, so placed that its width is precisely at right angles with an imaginary line drawn from its center to the center of the width of the sound track upon the film.

The light passing through the slit emerges in a thin line, or beam of light of somewhat greater width than the sound track. This beam passes through the slit assemblage objective lens, and is by it still further reduced in dimensions, until when it reaches the film sound track it is only .085 of an inch wide by .001 of an inch high.

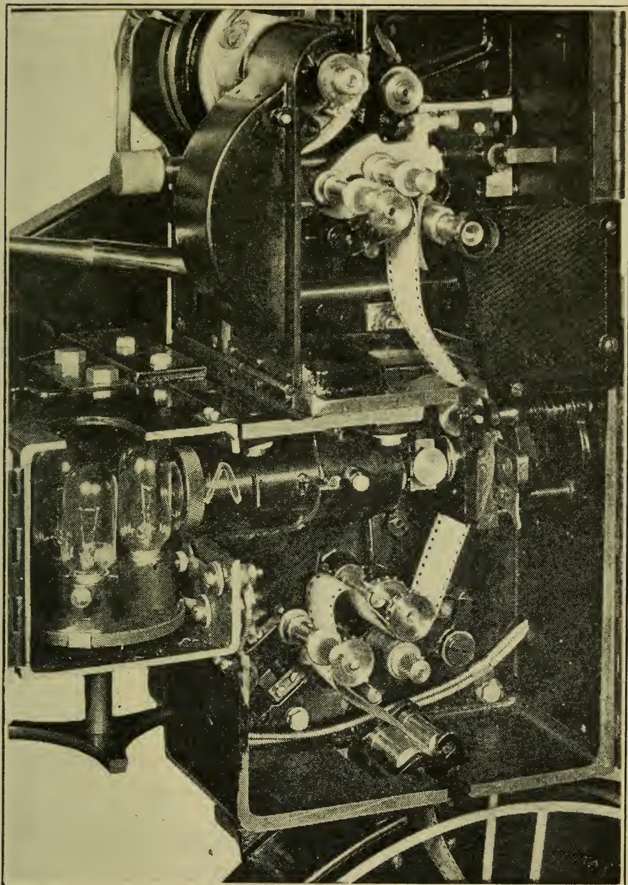


Figure 414.

The sound track itself is .070 of an inch wide, so that the light beam covers its entire width and overlaps on either side by .0075 of an inch. It is essential that this be so, for the reason that when using a variable area sound track such as is illustrated in Fig. 385, page 994, if the entire track width be not covered by the light beam, then some of the higher or wider peaks would not be illuminated throughout their entire length, with result that sound quality would suffer. The projectionist may test the side location of the light beam as per directions on page 1059, reporting any error found to the Service Engineer.

SLIT LOCATION.—The projectionist is warned not to meddle with the slit assembly. Its location is a matter for microscopic adjustment, which cannot be properly done by the projectionist. However, it is essential to excellence in results that the slit be so located that the beam of light will, at the point where it meets the film sound track, have its width precisely at right angles to the sides of the sound track. If this be not the case—**if the light beam be in any degree out of position in this respect—it will cover or "cut" more than one of the recorded lines simultaneously, with consequent distortion of the sound. Moreover, unless the light beam be properly focussed at the sound track there will be injury to the quality of the sound.**

Should the projectionist suspect the above described condition to be imperfect, he must not himself attempt to effect a remedy, but immediately notify an RCA Service Engineer, all of whom are supplied with the instruments necessary to the making of a competent test and a correct adjustment.

KEEP EVERYTHING CLEAN.—Projectionists are warned that oil, dirt and sound reproduction are implacable enemies. Everything in the exciting lamp and sound gate compartments must be kept scrupulously **clean.** Oil, dust or dirt in these compartments, or anywhere else about sound reproducing equipment, literally shout to Heaven of a careless, and therefore to that extent, inefficient projectionist. See page 1003.

PHOTO-ELECTRIC CELL.—After passing through the film sound track, the light beam passes on and into the photo-electric cell, the action of which is described

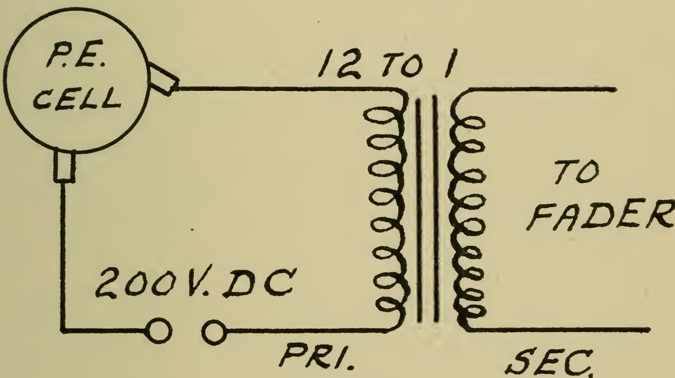


Figure 415.

Showing the General Hook-up of Photo-Electric Cell.

in detail under the title "Photo-Electric Cell," page 1013. There is, however, some slight difference in the interior light-sensitive coating of the one there described and the one used by RCA Photophone. Results are, however, generally speaking, identical. The interior coating of the one used with RCA is cæsium upon silver, instead of metal potassium upon silver as in the other tube. In the cell employed by RCA is a small amount of inert gas, as in the other. The cell is energized by a 200-volt D. C. battery, or its equivalent. This battery, or its equivalent, which in certain RCA Photophone installations is a motor generator set, see Fig. 418, is connected to the cell in series with the primary winding of a 12-to-1 step-down transformer.

The light fluctuations entering the photo-electric cell cause it to create a pulsating current (see pages 1013 to 1017) in the circuit, which same includes the 200-volt supply current and the primary of the transformer. This current energizes the transformer, causing it to step down, or reduce the voltage, bringing it down to one-twelfth (1/12) of its former value.

This step-down obviates the necessity for mounting a vacuum tube amplifier in the photo-electric cell compartment, or adjacent thereto, in order to eliminate the chance of microphonic noises affecting the extremely weak electrical impulses emanating from the photo-electric cell, which same might be set up by vibration of the projector mechanism.

This stepped-down current then is passed to the fader (which must not, in RCA apparatus, be confused with the volume control) and thence to the primary of another transformer—a 1 to 12 this time—mounted upon the main amplifier panel, which steps the voltage up again to its original value as it came from the photo-electric cell.

In brief, then, the entire sound reproduction system consists, in so far as has to do with its main parts, in (a) an exciting lamp; (b) a slit; (c) a slit optical system; (d) a film sound track; (e) a photo-electric cell; (f) a 200-volt storage battery or its equivalent;

(g) a 12 to 1 transformer; (h) a fader; (i) a 1 to 12 transformer; (j) a volume control; (k) various stages of amplification, and (m) loud speakers.

The amplifying circuit consists of three stages of push-pull voltage amplification. UX-210 RCA tubes are used, feeding an output stage of push-pull amplification through UX-250 or UX-845 tubes.

The amplified current finally passes through an output transformer and into the moving-coil cone loud speakers, by which sound is projected into the theatre auditorium.

INTERCHANGEABILITY.—RCA Photophone films may be projected with Western Electric apparatus, and variable density (movietone) films may be projected with RCA Photophone apparatus. In fact, at present at least, this is the case with all film carrying the sound record upon it. They may all be used with all sound apparatus designed for reproduction and projection, the sound track location on the film and distance from projector and sound aperture being standardized, the latter at 14½ inches.

DISC RECORD REPRODUCTION.—RCA Photophone supplies an attachment for the reproduction of sound from disc records. This apparatus is geared to run at the standard film-disc speed of thirty-three and one-third (33⅓) revolutions for each ninety (90) feet of film passing the projector aperture. Its operation is essentially the same as that of the one described in pages 1109 to 1113. In this connection you are referred to the matter appearing under "Using Disc Reproducing Apparatus," pages 1171 to 1181.

A change may be made from film to disc reproduction, or vice versa, merely by throwing a single switch, located on the projection room wall directly in front of the projectionist.

RCA AMPLIFIERS.—In the matter of amplifiers I am using matter supplied by the RCA Photophone engineering department, just as written, as follows:

RCA Photophone manufactures five types of amplifying equipment for the theatre installation, the type to be installed depending upon the size of the house and its acoustic properties. For the largest houses the equipment is known as Type "A," and for the smallest houses as Type "D," with the remaining types for intermediate size houses. There are two types of amplifying equipment known as the "B" equipment. These equipments are distinguished by the letters "MG" and "SPU." These two types of equipments have been designed for the same size houses. They differ only in the source of power, and for this reason have been given the same type letter.

AMPLIFIERS—TYPES "A" AND "B" (MG).—RCA Photophone manufactures two types of equipment supplied by power from motor-generator sets. Type "A" equipment consists of either two RCA Photophone projectors or two standard motion picture projectors equipped with RCA Photophone sound attachments, two amplifier racks, one of which is a spare, two 4-unit motor-generator sets, four storage batteries, twelve RCA Photophone electric-dynamic 12-inch cone type loud-speakers, and all necessary installation and operating accessories. The amplifiers, together wtih the 4-unit motor-generator sets and storage batteries, are furnished in duplicate. Only one amplifier is used for regular show operation. The other is kept in readiness as reserve equipment. In

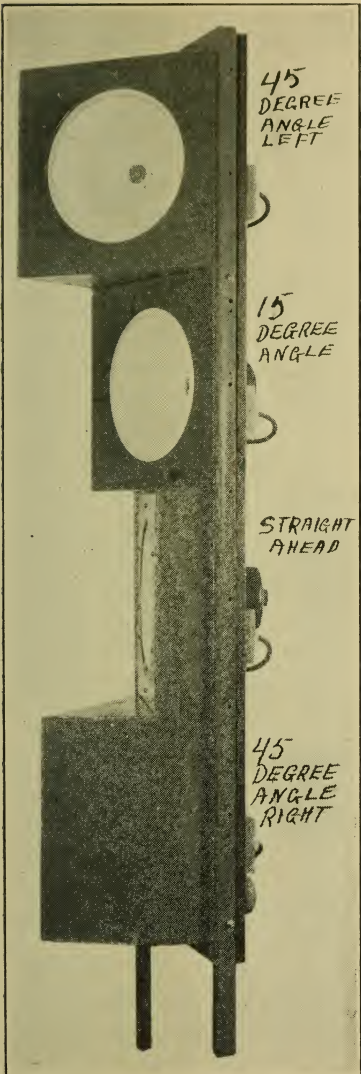


Figure 416.

RCA Photophone Loudspeaker Mounting.

Showing a bank of four RCA Photophone moving coil cone loudspeakers mounted on a rack beside the screen. It will be noticed that the angle of the speakers with respect to the front of the theatre is varied. The loudspeakers are arranged alternately at forty-five degrees, fifteen degrees, straight ahead, etc. The number of loudspeakers in a bank depends upon the size of the theatre. Installations vary from four to twenty-four loudspeakers, utilizing two banks, one on each side of the screen.

The loudspeaker racks are either rigidly attached to the screen and flyed with it, or flyed separately. In some instances the racks are mounted on rollers and pushed off to one side in the wings when not in use.

case of an emergency it may be placed in service in a very short time.

The power supply for the 4-unit motor-generator sets may be either 110 volts D. C. or 220 volts, three-phase alternating current. Each of these MG sets is provided with approved fused line switches, and with automatic starters, remote controlled from the amplifier racks.

The Type "B" (MG) equipment consists of two RCA Photophone projectors, or two professional projectors equipped with RCA Photophone sound attachments. One amplifier rack, one 4-unit motor-generator set, two storage batteries, twelve RCA Photophone electro-dynamic 12-inch cone loud-speakers, and all necessary installation and operating accessories. The amplifier used in this equipment consists of one voltage amplifier and two power amplifiers. Normally the two power amplifiers are used, each amplifier operating six of the 12-inch dynamic cone speakers. The power amplifiers are so arranged that in case one fails, the show can proceed with one amplifier. The 4-unit motor-generator set used with the Type "B" amplifier is similar to the one used in the Type "A" equipment.

The Types "A" and "B" equipments are similar in construction and operation. The Type "A" equipment has duplicate amplifier racks and affords a complete standby equipment, whereas the Type "B" equipment has one rack and two power amplifiers, and in case of emergency this equipment may be operated with only one of the power amplifiers.

It is to be noted that all power for the "A" and "B" (MG) amplifier is supplied by motor-generator sets, which eliminates the necessity for batteries. The two storage batteries with each equipment are used as filters to smooth out generator ripple. They are not used as a source of power.

AMPLIFIERS—TYPES "B" (SPU), "C" AND "D."—RCA Photophone manufactures three types of amplifiers which are operated from a regular 100-volt, alternating current lighting circuit. The smallest of these is known as Type "D." It is installed in houses with a seating capacity of 750 or less. With this type equipment two RCA Photophone projectors or two professional projectors with Photophone sound attachments are installed. The same applies to the Type "C" equipment which is used for houses seating up to 1,500, and the Type "B" (SPU) for houses larger than 1,500.

With each of these equipments an input control panel is located on the front wall of the projection room. This panel has meters and rheostats for controlling the current in the photo-cell exciter lamps; a change-over potentiometer (Fader) for changing from one projector to the other; a volume control and a volume indicating meter. Unlike the two equipments previously described, these types have no high voltage lines entering from the outside, but are constructed with rectifying units for supplying plate voltage. The three types are essentially the same, the only difference being in the number of units installed.

The Type "D" equipment has one voltage amplifier unit and one power amplifier unit. It operates four 12-inch dynamic cone loud-speakers. The Type "C" equipment has two voltage amplifier units, one of which is not in use but is held as reserve equipment, and two power amplifier units, both of which are in use feeding

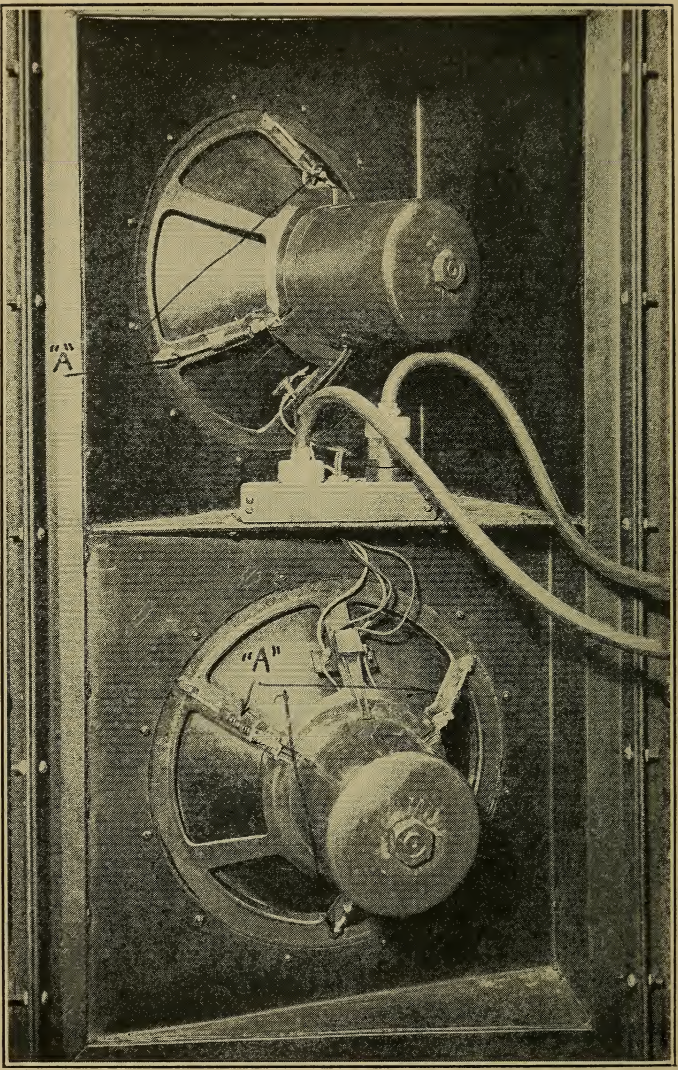


Figure 417.

Back View of RCA Photophone Loudspeaker Mounting. Fig. 417.

Two of a bank of RCA Photophone moving coil cone loudspeakers mounted in a rack for theatre installation. Notice the angular location of the cones with respect to the front face of the rack. The upper cone is set at forty-five degrees and the lower cone at fifteen degrees. Connections are made to cables running in two pipe conduits at the side, as can be seen in the illustration.

It will be noticed that adjusting rods and springs ("A") are located along three of the spiders comprising the frame of the loudspeakers. These rods connect with fine cords which are tied together at the center of the cone apex to keep the cone centrally located in the assembly. Adjustment to the central setting is made by means of the rods. This is done only by RCA Photophone service engineers.

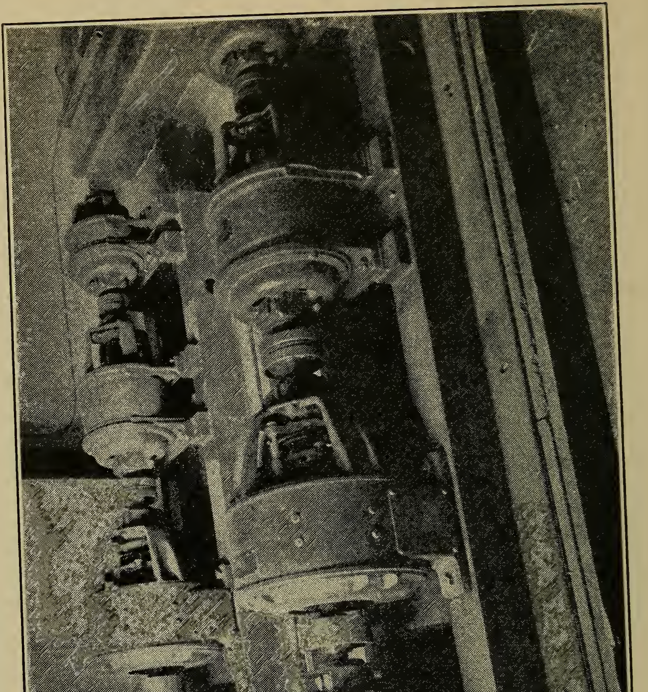


Figure 418.

RCA Photophone Motor-Generator Equipment.

Fig 418 shows two motor-generator units as supplied with the larger installations of RCA Photophone reproducing equipment.

The four-unit machines are composed, each, of three generators and a driving motor.

—From left to right: 500/1000-volt generator for supplying plate current to all tubes, and polarizing voltage to photo-electric cell; driving motor (for 220-volt, 60-cycle 3-phase operation in A. C. supplied installations, or for 125 volts D. C. operation in D. C. supplied theatres); 15-volt generator for supplying filament current to all tubes, pilot lights and exciter lamps; 250-volt generator for supplying field current to the other generators, bias "C" voltage to the power tubes of the amplifier, and field current to the loudspeakers.

eight dynamic speakers. The Type "B" (SPU) has two voltage amplifier units, one of which is reserve equipment, and four power amplifier units, all of which are used to operate sixteen loud-speakers. In case of trouble with the voltage amplifier unit it is possible to switch to the reserve, merely by throwing a series of three switches. This operation takes less than one-half minute. In case of trouble with a power amplifying unit, this particular unit is cut out and the show run on the remaining units.

Each power amplifier and voltage amplifier unit is provided with its own controls and is operated independently of the others. All of these amplifiers use the standard RCA Radiotrons. Filament current for the voltage amplifier units, and for the photo-cell exciter lamps, is furnished by a storage battery. Each installation has two storage batteries, one for use while the other is being charged. All wiring from the projectors to the amplifiers, and from the amplifiers to the batteries and loud-speakers is in suitable conduit and concealed. For installations where the theatre does not have 110-volt, 60-cycle alternating current supply available, convertors or transformers for changing to such power are installed. Two convertors are supplied with Types "C" and "B" (SPU) equipment, one to be used as standby equipment. With the Type "D" equipment only one convertor is supplied.

The equipments outlined above present certain advantages, as follows:

1. All controls necessary for running the show, changing projectors and controlling volume are located on the front wall of the projection room, directly in front of the projectionist and easily accessible.

2. Adequate reserve apparatus is provided in the larger equipments, so that the show will go on even in an emergency.
3. All outside power to the amplifiers is furnished by regular 110-volt, 60-cycle alternating current lighting supply.
4. All high voltage is completely enclosed within the amplifier, and the amplifier itself is enclosed in a metal case.
5. The Type "D" installation can be converted into the Type "C" installation in a very short time, by the addition of one voltage amplifier unit and one power amplifier unit with proper inter-connecting cables.

INPUT CONTROL PANEL.—Fig. 419 affords us a view of the RCA Photophone input control panel. A indicates the knob by means of which the volume of sound is controlled. It will be observed that there are twenty-six (26) steps, each one of which means a difference in sound volume.

In the upper right hand corner we see three small lamps, one of which is white, one red and one green. These are for use by an "observer" located in the auditorium during the cueing of a production, or at other times if desired. When the top, or red lamp flashes, it means increase volume one point. If another point then is desired, the lamp flashes again. Or the light may be held on until the desired volume increase has been reached, which is accomplished by advancing the knob A pointer a step at a time. Or it may be arranged that when the red flashes, the volume is to be slowly advanced until the white (center) lamp is flashed, which means "hold position." The lower or green lamp flashing means lower volume. It is an excellent arrangement.

Immediately beneath knob A is knob B, by means of which the sound change is made from one projector to another. When the pointer is at ten (10) on the left side, then the left hand projector (projector No. 1) is in circuit. When the pointer is at ten (10) on the right scale, then the right hand projector (projector No. 2) is in circuit. When the pointer is at **"off"** at top of scales, then both projectors are cut out.

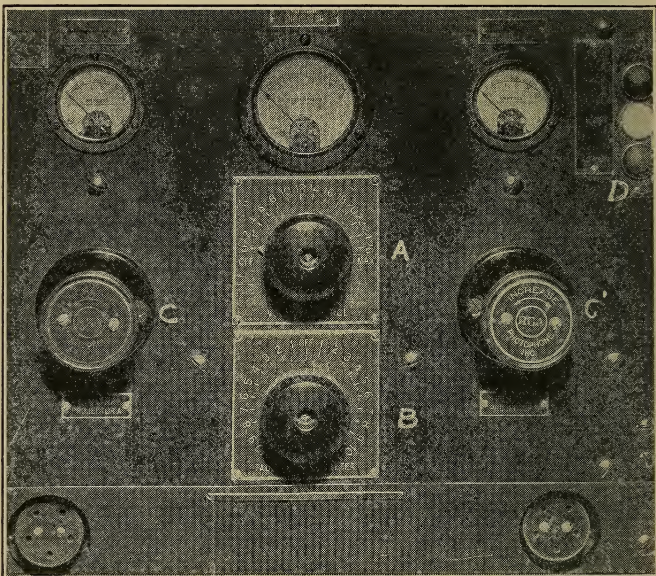


Figure 419.

Knobs C and C′ control rheostatic resistance by means of which the exciting lamp current is controlled. The center meter above is a reading of the current flow which represents volume. This reading will be different for different settings of volume control knob A. At the bottom of the panel we see two circular plugging jacks. Cables connecting the panel to the projectors are plugged into these.

SOUND CHANGE OVER AND VOLUME CONTROL.—In this arrangement it will be observed that "fading" the sound and changing from one to another projector is taken care of by two separate instruments controlled by knobs A and B.

When the change-over is to be made, volume is not in any way disturbed, since knob A, which controls it, remains stationary. Knob B handles the change-over, and when it has been swung from ten (10) on one side to ten (10) on the other side, the volume will be exactly what it was on the projector which was cut out, assuming the performance of the exciting lamps and slit optical systems of both projectors to be identical—which they should be.

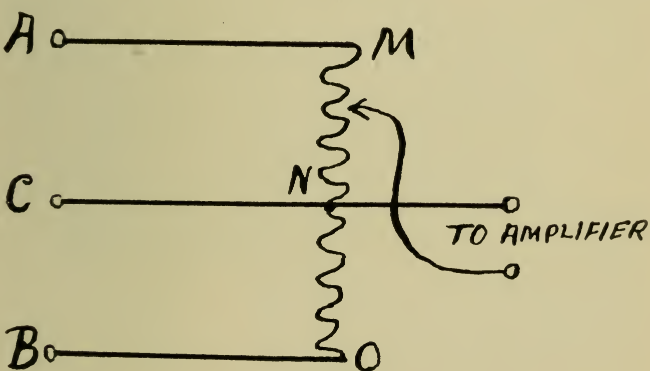


Figure 420.

Knobs A and B operate precisely the same for both disc record and sound-on-the-film reproduction. The action of this system may be made more clear by an examination of Fig. 420, in which the input from projector No. 2, or turntable No. 2, is connected to terminals A-C, and the input terminals of projector No. 1 to terminals B-C. The diagram of course only shows the essential connections. As the movable arm, represented by the arrow, progresses from position M to position O it is seen that the input from A-C is "faded" out and that from B-C is substituted. Terminals X-Y lead to the input of the amplifying system.

The resistance steps of M-N and N-O are so designed that sudden changes in volume of sound are impossible.

The resistance steps from ten on the left to ten on the right are merely transitional steps. The operating position is always ten (10), at either end of the scale. Moving knob B moves the arm along the series of resistance coils between M and N and N and O, reducing voltage values progressively to N and increasing them progressively to O. The change-over is made by a quick turn of the knob through its maximum possible movement.

The Powers Cinephone

THE Powers Cinephone uses the variable density sound track, shown in Fig. 383, page 981. The sound attachment may be had to fit any of the profes-

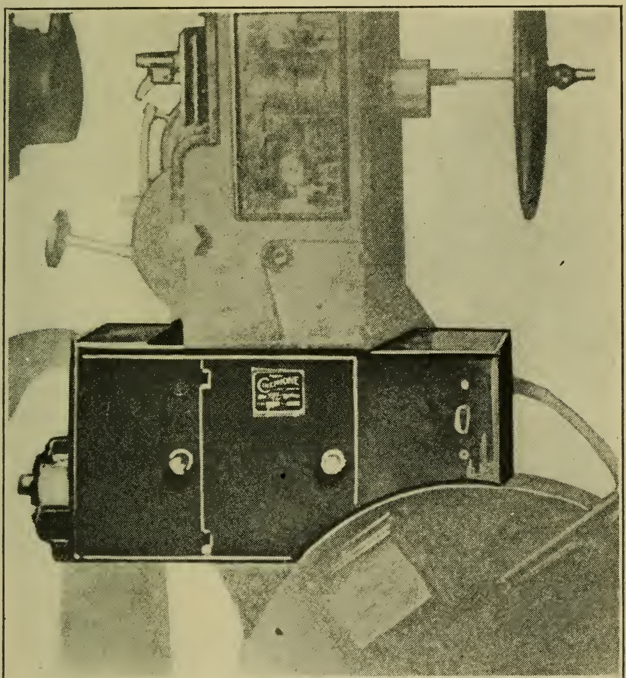


Figure 421.

sional motion picture projectors. It is compact, well made and has all the necessary things to enable the projectionist to handle it effectively and efficiently. It is shown in Fig. 421, attached to a Simplex projector.

The general arrangement of the elements is the same as that of other systems. There are three compartments,

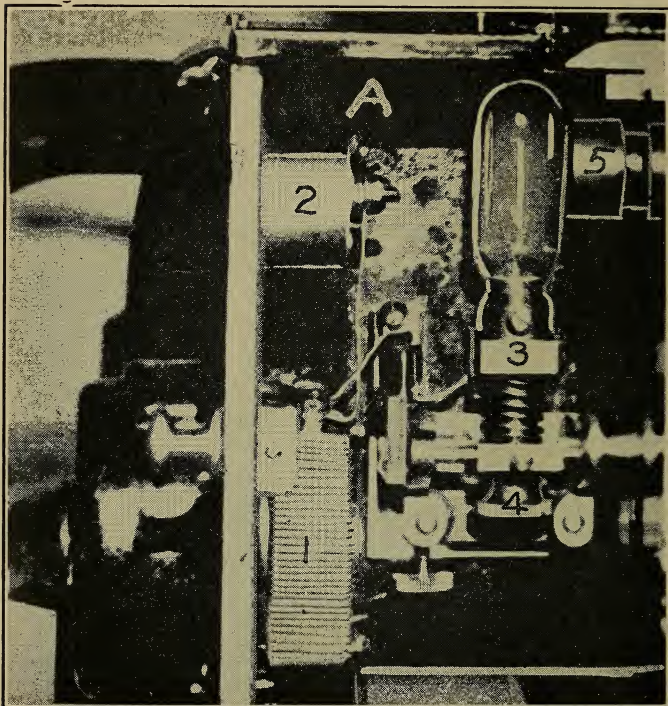


Figure 422.

one containing the exciting lamp and what goes with it; one the sound gate, sound sprocket, etcetera, and the other the photo-electric cell. The interior of the exciting lamp compartment is shown in Fig. 422, in which 2 is the meter registering the exciter lamp current, which must

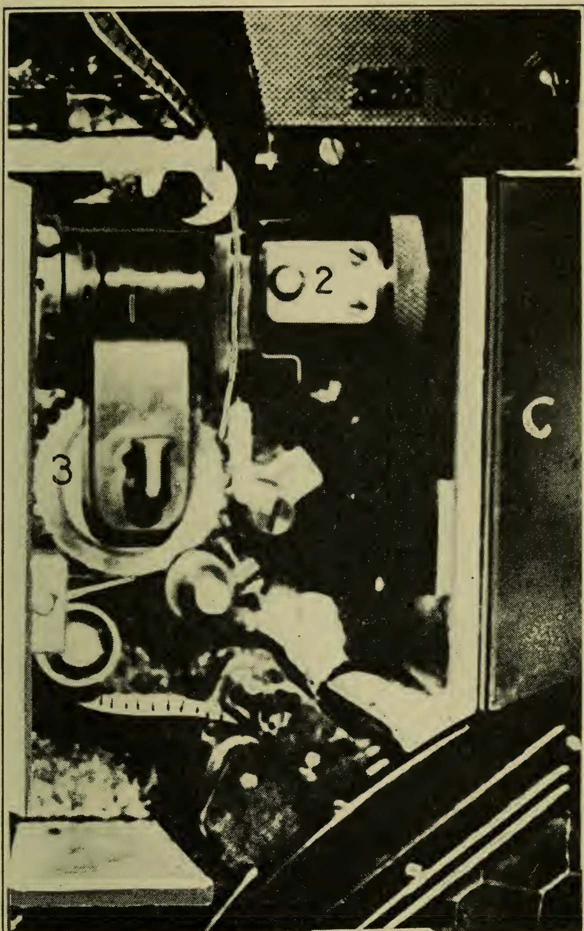


Figure 423.

be kept exactly at four (4) amperes. 1 is the rheostatic resistance by means of which the exciter lamp current is controlled. 3 is the exciter lamp socket and 4 the thumb screw by means of which the lamp may be adjusted vertically—up or down. 5 is the rear end of the slit optical system, which is essentially the same, in its general make-up, as that described on pages 1102 and 1107. Its adjustment and treatment would be essentially the same as the one there described, though the exact mechanical details will be found somewhat different. The thing to remember regarding all exciting lamp optical systems is that the length or "width" of the slit must always be precisely at right angles to a line drawn from its center to the center of the sound track, and that the light must be properly centered and focused at the sound track. See page 1106.

In Fig. 423 we have a view of the interior of the sound gate compartment, through which the path of the film may be traced by the white line. 1 is front end of the barrel containing the slit optical system. 3 is the sound sprocket. In this equipment it is essential, as in all other equipments, that the lower loop of the projector be so formed that there will be precisely fourteen and one-half (14½) inches of film between the center of the projector aperture and the center of the sound gate aperture. You will be instructed in the setting of this loop by the installation engineers.

Compartment C, immediately in front of the sound gate compartment, contains the photo-electric cell, the construction and operation of which is set forth on page 1013.

To give explicit instructions for this equipment, in so far as it is our intention to give instructions in operating

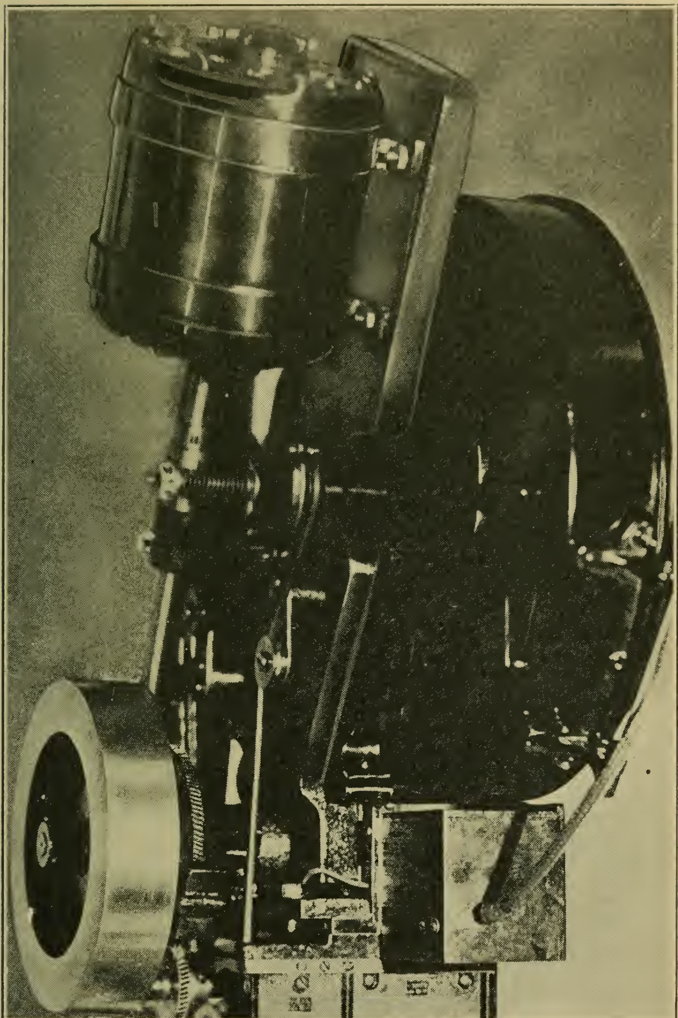


Figure 424. Motor Driving the Equipment and the Method of Its Attachment to the Projector.

details in this work, would only be a repetition, since the principles underlying it differ in no degree from those underlying the other systems described. The only difference lies in the details of construction, and in such matters the manufacturer will fully inform you when the equipment is placed in your charge.

On the wall directly in front of the projector is mounted a two-stage amplifier, which the current from the photo-electric cell passes through. This amplifier uses 112-A tubes.

MAIN AMPLIFIER.—The Cinephone main amplifier consists of two complete amplifier and power systems. The connection is such that merely by moving switch J, Fig. 425, the change is made from one to the other. By this it is meant that should one amplifier for any reason become defective, a change to the other complete amplifying unit may be made by throwing switch J. It is a good arrangement.

Referring to Fig. 425, A is the main A. C. switch for amplifying system. B is charge-discharge switch for batteries supplying the amplifiers next the photo-electric cell. C is the A. C. switch for charger circuit. D is the charge-discharge switch for the exciter lamp and main amplifier battery. E is the motor generator switch, to be used in territory where power is other than 110-volt 60-cycle. F is the charge-discharge ammeter for circuits terminating at switch B. G is the voltmeter for measuring the voltage across the filament of vacuum tubes in main amplifier. When batteries are fully charged, this meter should read 12 volts. H is the charge-discharge ammeter for circuits controlled by switch D.

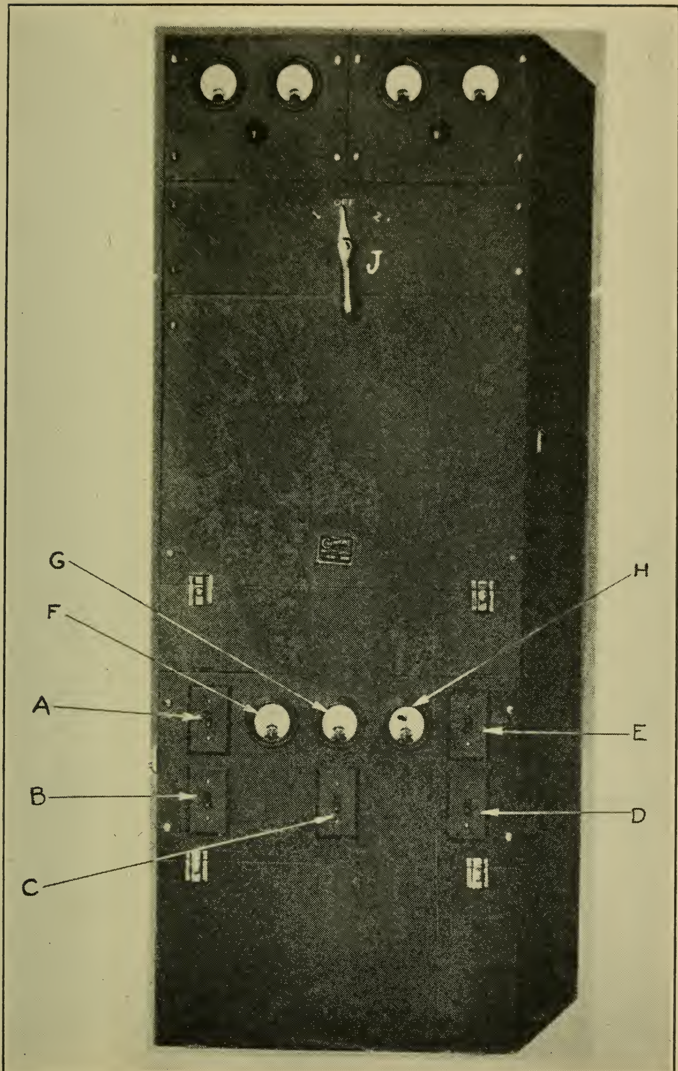


Figure 425.

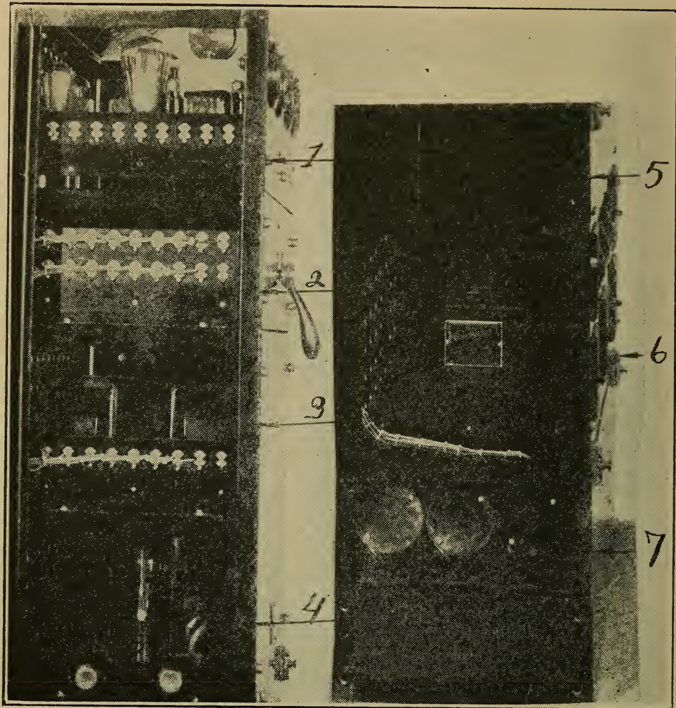


Figure 426.

IMPORTANT.—This is a side view of the main amplifier shown in Fig. 425, with one side of its casing removed. In order to make a picture with less reduction I have cut the photograph in half. As a matter of fact the part at the left is the top part of the amplifier and normally sits on the part at the right.

Fig. 427 shows interior view of fader with cover removed. The main parts are disclosed to view. Each of the round buttons represents a short coil of resistance wire immediately behind it and connected therewith. The round belt connects the fader with a "dummy" located in front of the projectionist when he is in working position beside the other projector.

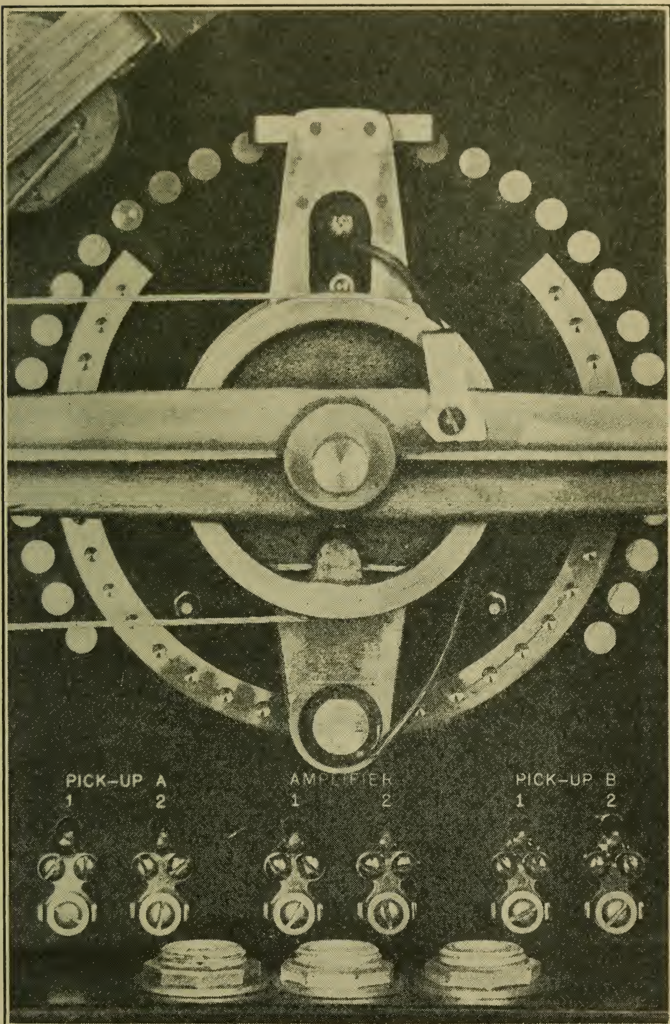


Figure 427.

The switch handle beside the figure "2" is switch J, Fig. 425; the switches shown between the figures "5" and "6" are switches A-B, etcetera, Fig. 425.

In Fig. 426, 1 is the amplifying panel, access to which is had either from the top or side, doors being provided at both places. 2 is the compartment or panel containing the switch mechanism by means of which transfer is made from one amplifier to the other. 3 is the panel or compartment containing the power supply for No. 1 amplifier. Access is had to it from its side. 4 contains the power supply for amplifier No. 2. 5 contains the "B" batteries for the photo-electric cell and its amplifier. In 6 is the charger for the "A" battery, while compartment 7 contains the "A" battery for the complete system.

DISC REPRODUCTION.—See pages 1171 to 1181. There is, of course, a turntable for disc record sound reproduction. It is both mechanically and electrically coupled to, or interlocked with, the motion picture projector. The mechanical locking is accomplished by means of a flexible shaft connecting the motion picture synchronous motor and a similar synchronous motor mounted within the disc turntable. Not a very satisfying setting forth of the arrangement, but all sound equipment manufacturers are tremendously busy and it is difficult to get things just the best way.

Using Disc Reproduction Apparatus

NOTE.—I am indebted to Mr. Boris Medove, Chief Projectionist, Park Plaza Theatre, New York City, for his helpful co-operation in the preparation of this subject.

TO "set up" for sound disc operation, a certain fixed routine is essential to surety of perfect operation. It, together with certain other necessary things, is treated under this head. It is advised that projectionists using the disc method not only study the operating instruction book supplied by the manufacturer, but also study this matter and give heed to its suggestions.

(a) The projectionist who expects to secure uniformly good results will either cue his own picture, or else very carefully check the films with the cue sheets which accompany it.

(b) He will, when using a Simplex projector mechanism, locate starting marks as per Fig. 428. When film is received to which a good leader is attached, then he may cut off a piece of film, white leader or otherwise, one sprocket hole in length, and cement it to the leader in position A, so that its upper edge will come flush with lower edge of aperture plate when start frame is in proper position over aperture.

IMPORTANT.—When some projector mechanism other than Simplex is used, then the same procedure may be followed, except that the distance will be different from "start" to A. However, the exact distance may be easily determined by laying a strip of film on the aperture plate, with one frame in position over the aperture, and counting the number of sprocket holes to bottom of aperture plate, or other locating point selected.

(c) The projectionist should start his amplifier equipment as follows:

(1) See to it that all starting switches are in **"off"** position.

(2) See to it that the battery switch is ready for use as per the Electrical Research Products, Inc. (ERPI), instruction book.

(3) Close A. C. supply switch.

(4) Close filament switch and let filament warm up for at least five minutes.

(6) Switch on plate current.

(7) Close horn safety switch and make certain that relay switch in fader panel is set for disc reproduction.

(8) Make sure that disc-film transfer switch is set at "Disc."

Having attended to all these matters, in their order as set down, you are now ready for disc sound reproduction in synchronism with motion pictures, in so far as concerns the amplifying equipment.

However, there is much which must be done before setting up for reproduction, if perfection in results are to be insured, and unless the things we shall set forth are **all** done, there will be no insurance of perfect reproduction.

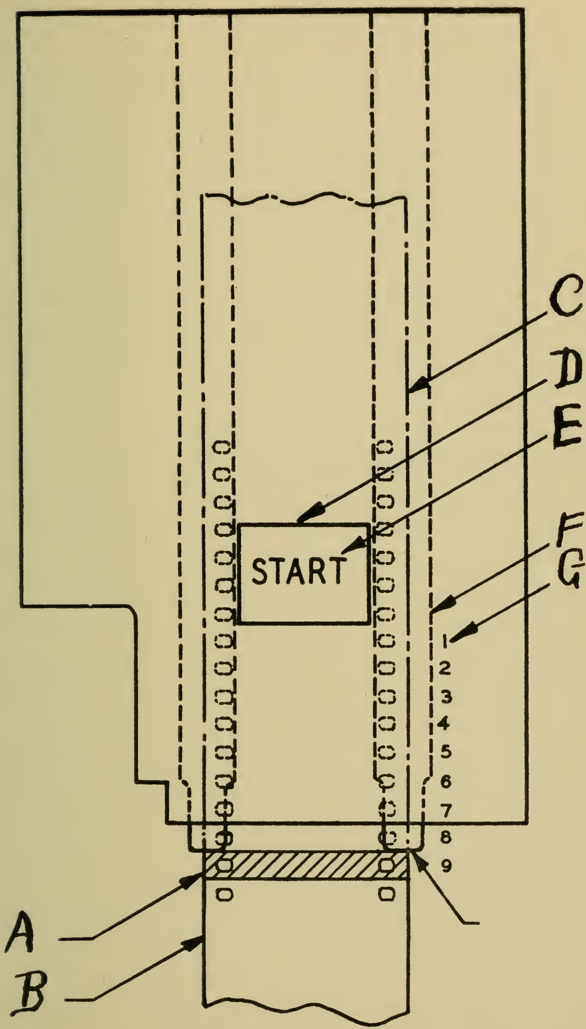


Figure 428.

A—Splice between white leader B and film C. E—Projector aperture. Starting frame must be set exactly in frame over projector aperture. F—Aperture plate film track. G—Number of sprocket holes from bottom of starting frame to lower end of aperture plate.

(d) The projectionist must monitor or test his records before attempting to use them in his show. This is done as follows: Place record on turntable in the manner shown in Fig. 430. Set needle at starting mark. Bring fader up to its normal operating position and start projector, counting the number of turntable rotations and fractions thereof before sound starts. Exact counting will be made the more easily if a bit of white paper be placed under the record edge opposite the starting mark. Using a China Marking Pencil, mark each record with the required number of turns as per the count. The records are now ready for use in the regular rehearsal.

In theatres where managers class the first show as "rehearsal," use the following method to mark records: If it requires about five seconds for a projector to attain full speed, it then follows in that time the turntable and record have made one and one half (1½) revolutions, and about four feet of film has passed the projector aperture.

In the same time, however, since at full speed (90 feet of film per minute, or 1½ feet per second) seven and one-half feet of film has passed the aperture of the other projector, therefore after having tested the record and found that, for example, it requires three complete revolutions from starting mark for sound to start, it is safe to rotate the record one and one-half (1½) revolutions from the starting point, thus leaving 1½ revolutions to permit projector reaching full speed before sound starts. Therefore mark the record, using a red "china marking pencil," 1½, which means you are to place needle on starting point of that particular record and operate the projector by hand until the record has rotated 1½ turns.

NOTE.—Of course if you are projecting over or under 90 feet of film per minute—which you should **never do**—then you will have to figure distances differently. For example, as to the working projector, if the speed is greater than 90, then more than 7½ feet of film will have passed in five seconds; also it will require probably an added second of time for the projector you are starting to reach maximum speed, all of which must be taken into account.

(e) **NEEDLES.**—The needles supplied are usually far from perfect. The careful, painstaking projectionist will examine all needles, rejecting any which have not a perfectly sharp point when examined under a magnifying glass. **The management should supply a good glass for this purpose.** It will pay them to do it. A good, strong reading glass will serve very well. One may even use a condenser lens, but, while better than nothing, it is unsatisfactory.

Grade needles as nearly as possible into lots of equal length and diameter. Examined under a glass, needles will be found to vary more or less both in length and diameter. If a needle be thicker and (or) shorter than the one it displaces in the reproducer, then the resultant sound will be materially altered. It will be both louder and more harsh. Long, thin needles tend to produce soft, low music or speech. Conversely, thick, short needles make for loud, harsh sound.

With the aid of a good glass and an examining board, enough needles may be examined and graded in half an hour to last for at least a month of operation, and it will be time well expended.

(f) To construct an examining board, secure a board of any convenient width greater than, say, two inches, with one of its edges perfectly straight. That last is important. From one foot to eighteen inches in length will be ample and convenient. To its straight edge attach a wooden strip, either by small nails or screws, permitting it to extend above the surface of the board by at least one-eighth of an inch. The end of such a board is shown in Fig. 429. Next measure the length of one of the needles you are using and, using a straight-edge, draw a pencil line on the surface of the board a distance from the backing strip equal to the length of the needle you measured. The board is now done, except that you might nail a strip at either end to prevent the needles from rolling off.

Figure 429.

To examine needles, lay them in a row, butts to the backing strip. The line on face of board will help detect variations in length. If you have a machinists' scale or other piece of metal six inches to a foot long, you may detect and remove undersize needles merely by pressing the bar down on the row of needles, at the same time tipping the board. The small needles will of course slip out, and may be placed by themselves.

However, this latter method of separating the small diameter needles must be used carefully. Wood has a certain amount of resiliency and if you press too hard the thicker needles will sink into it enough to permit of the bar clamping the smaller ones enough to hold them. As a matter of fact the theatre will do well to provide a cast iron needle testing block. Any machine shop possessed of a planer would make one for a small sum.

It really need not be more than six or eight inches long, by an inch and a quarter wide, if made of metal. It would have the advantage of being perfectly true and unresilient.

(f) **STARTING THE SHOW.**—(1) Make sure that the reproducer arm swings perfectly free. Any binding may and probably will cause it to jump the record grooves, and thus ruin the synchronism. An ounce of prevention (testing) is worth several pounds of excuses. Don't take things for granted. **Test them.**

(2) Select the record to be used. **Check its number against the film number.** Check the number of times used, including this show. Don't neglect these things. Do your work **right.**

(3) Set the projector mechanism framing lever in mid position. Rotate the mechanism flywheel until the exact point at which the intermittent movement has ceased to act is ascertained—intermittent sprocket has ceased to move—and then thread in the film, as follows: At the beginning of each reel you will find a frame marked **"start."** Place this exactly in frame over the aperture. In this connection see Fig. 428 and instruction (b), page 1171.

IMPORTANT.—In this connection, when the exact point at which the intermittent sprocket has ceased to move has been ascertained, since it must be thus located every time a disc sound reproduction film is threaded in, the operation of finding it will be much simplified if a white mark be made on the rim of the rotating shutter opposite some convenient fixed mark. Or a stiff wire may be attached to the wall or some portion of the projector mechanism, its end near the shutter rim, and the mark on the shutter rim made opposite it. This is not, of course, a matter of necessity, but rather of convenience.

(4) Place record on turntable in accordance with following. **Important:** To avoid possible damage to record and failure of synchronism, it is imperative that the driving motor remain absolutely stationary while record is being placed and adjusted on turntable.

(5) Handling the record carefully, and with **both** hands, lay it on turntable in such position that when the reproducer arm is swung into position the needle point will come approximately at record starting point.

(6) Wipe off the record gently but thoroughly before placing arm in starting position, using the cleaner provided by preference, but in no event a harsh or dirty cleaner. Permitting dust to remain on a record will not only serve to work injury to the record itself, but also it will injure the quality of the reproduced sound, and increase "surface noises."

(7) Having the record in place and perfectly clean, grasp the end of reproducer between thumb and forefinger of left hand (it really does make a difference just how things are done, so train yourself to do them the **right** way) in such manner that the tips of thumb and finger project half an inch or so below bottom of needle point. Move reproducer over until needle point is above starting point, resting thumb and finger on surface of record so as to hold needle point just clear of the groove.

(8) Holding needle as above, place right hand as shown in Fig. 430, with fingers pressing lightly upon under surface of turntable and thumb on upper edge of record, as shown. Hold turntable steady while you,

using the thumb, move the record to a position where the starting point, indicated by arrow, comes directly beneath needle point, carefully remembering that "directly" means **exactly.** Absolutely no error is permissible here.

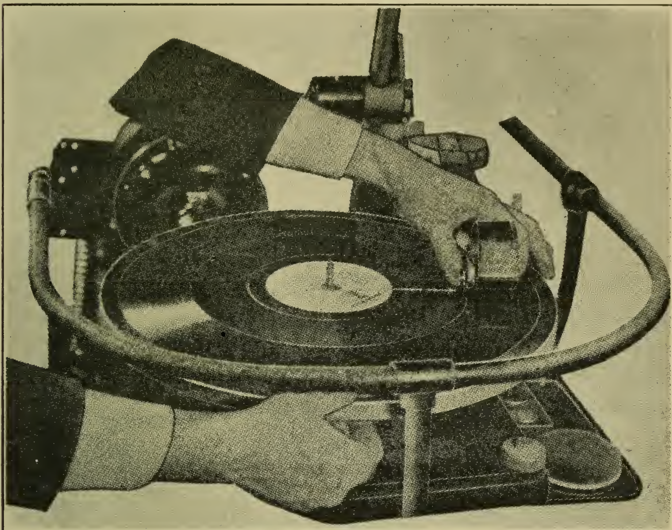


Figure 430.

(9) Having followed the preceding instruction **exactly,** gently lower the needle point into the groove. **Warning:** Do **not** lower the needle point upon the smooth, uncut surface and slide it sidewise into the groove, unless you are **hunting for trouble.** Lower it straight down, and **gently.**

(10) When you have the needle point in place, resting the fingers **lightly** upon the reproducer top, try **gently** to move it sidewise in each direction. This is to make

certain the needle point is in the groove. Place the record clamp over the turntable center pin, pressing it down firmly, but not too hard.

(11) Rotate motor flywheel by hand until turntable has revolved the required number of times, as per its marking, see instruction (D), seeing at the same time that the needle tracks properly on record, and that the film moves as it should. Having completed this you are ready to start the projector, or if it be the first reel, the show.

(12) See to it that the fader is at zero; that relay switch and pilot light is on "Disc" and that your motor control box is on regular setting.

(13) Close the projector motor switch, and as soon as full speed is attained, bring the fader up to its proper setting. Do **not** swing it up suddenly, but with moderate speed. Experience will quickly teach you just how fast to raise the volume—advance the fader pointer.

If it be a change-over, you should have the picture cue far enough from the end to permit the other projector to attain full speed before change-over, and with most projectors this requires about six feet of film. You will, however, do well to test each projector, since some will attain full speed somewhat more quickly than others. **Be sure not to move the fader over until the other projector has attained full speed.** If you do there will be a very bad effect.

(14) The projectionist should carefully watch the action and compare it with the sound at each change-over, since there is always the possibility of something happening at change-over to injure synchronism. **Important:** If it is found that there is an out-of-synchronism,

but that it is slight, **it may be adjusted merely by swinging the entire reproducer arm bracket slowly backward or forward.** If the effect is "late," then the arm must be swung forward; if it be "early," then swing it backward—backward as the record turns.

NOTE.—This latter applies only to the earlier types of Western Electric apparatus.

However, if the out-of-synchronism is out so much that it cannot be thus remedied, then it is up to the judgment of the projectionist whether to continue, or to bring the fader to zero, stop and re-set both film and record, remembering that if he continues it will be impossible to regain synchronism until the entire reel has been projected.

(15) **IMPORTANT.**—Never attempt to stop or slow up a projector by holding your hand on the turntable with a braking effect. If you do you may and very likely will damage the apparatus. Certainly you will strain it, besides throwing the record out of synchronism with the film. The turntable will rotate several times after the current has been switched off the projector driving motor and projectionists have been known to damage the apparatus badly by applying their hand to the turntable as a brake. **Don't do it!**

(16) The disc turntable used with Western Electric Equipment rotates 33⅓ times to each 90 feet of film projected—in other words, 33⅓ times per minute at the normal speed of projection.

If you don't know exactly what an amplifier is and how it works, how do you expect to handle it intelligently and efficiently?

Film Inspection Mechanism

IT would seem reasonable that any device which makes for improved film inspection, or in any way tends to reduce damage to films, may well be included in a book dealing with sound projection.

That view is based on the fact that with the advent of sound came the added amount of damage to results, as heard and viewed by audiences, set up by mechanical faults in the films.

This is true both as to film which carries the sound record, and film which is synchronized with sound carried on a disc record, the latter because of the fact that small faults which might be passed by in a hand inspection, may rapidly grow into larger ones requiring the making of splices, with the elimination of film incident to that process. And as you know, if any film be cut out of film synchronized with sound carried on a disc record, it must be immediately replaced, either with opaque blank film or by the insertion of an exact duplication of the piece which was eliminated. If this be not done, then the sound will be thrown out of synchronism with every following projection of the film.

There is now on the market a film inspection mechanism originally designed for use in exchanges only, but now available in a theatre model, which is little less than uncanny in its detection of even the slightest film fault.

The device has been carefully examined by the author, whose hearty approval it has. It may be set to detect faults only, or may be set to permit the examination of every splice in the film. If so set, then every splice which passes the detector automatically stops the mechanism, which must be started again by the attendant after the splice has been examined.

If set for faults only, then the mechanism stops automatically when anything in the nature of a fault passes the "detector." Even the splitting of one division between two sprocket holes will act to stop the mechanism, which must be started again by the attendant.

The speed of inspection is 225 to 250 feet per minute. There are no sprockets. Nothing touches the emulsion side of the film in its passage through the mechanism. It rewinds the film into a firm roll, without slippage, hence causes no "rain" in the process of inspection and handling by the machine.

The machine is one of precision, yet is dependable in that it is quite simple, easily handled and unlikely to get out of order.

There are several advantages incident to thorough film inspection which the average theatre manager and projectionist do not ordinarily consider. For example, thorough inspection and repair of film reduces the fire hazard very decidedly. In fact, it may almost be said to eliminate it since in at least nine cases out of ten film fires have their inception, in one way or another, in faulty film. Thorough film inspection is an insurance against programme interruptions. They also, if carried out in all theatres, are in the nature of an insurance against receiving films in poor condition, to the consequent damage of your own show.

That really sounds like a selling talk, but whatever it sounds like, it is just cold **facts.**

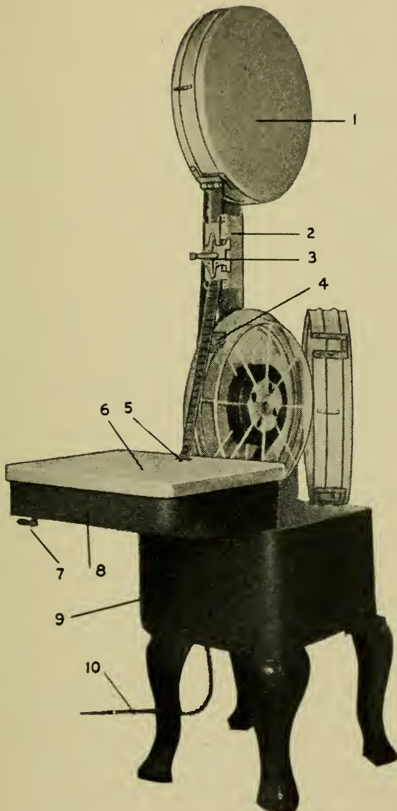


Figure 431.

The device is driven by either a D C motor, with its detector which energizes a specially wound D. C. magnet coil, or by an A C motor, with its detector which energizes a special A. C. magnet coil, according to the kind of supply current available to the theatre.

The take-up is of the friction disc type. It is adjustable. Fig. 431 shows the machine as a whole, with the lower magazine door open. The magazines are 17 inches in diameter. 2 is the detector box, shown in detail in Figs. 2 and 3. Part 8 houses the mechanism shown in Fig. 432. 7 is the handle or lever by means of which the mechanism is put into operation. The film passes through slot 5 and thence into the lower magazine. The table, 6, Fig. 431, is of ample size for making film repairs. I would respectfully suggest to the manufacturers that a good splice-making device attached to the table would be a desirable addition.

In Fig. 432 we have a side view of the fault detecting mechanism contained in casing 2, Fig. 431. The detector casing is held to the machine frame by two bolts, the upper one of which is indicated by 11.

12, Fig. 432, is one of the four nuts by means of which the tension (supplied by a coil spring) of the detector is adjusted, the coil spring itself is numbered 13. At 14 are tungsten contact points which close whenever either of the four detector fingers pass over a defective portion of the film, or, if set that way, over a splice. The closing of these points automatically stops the mechanism. 18 are the binding posts to which the electric circuit attaches.

Fig. 433 is a view of the film track and gate of the detector box, the gate being in open position. Above is the lower edge of the upper magazine and at the left the supporting column. The detector box really is attached

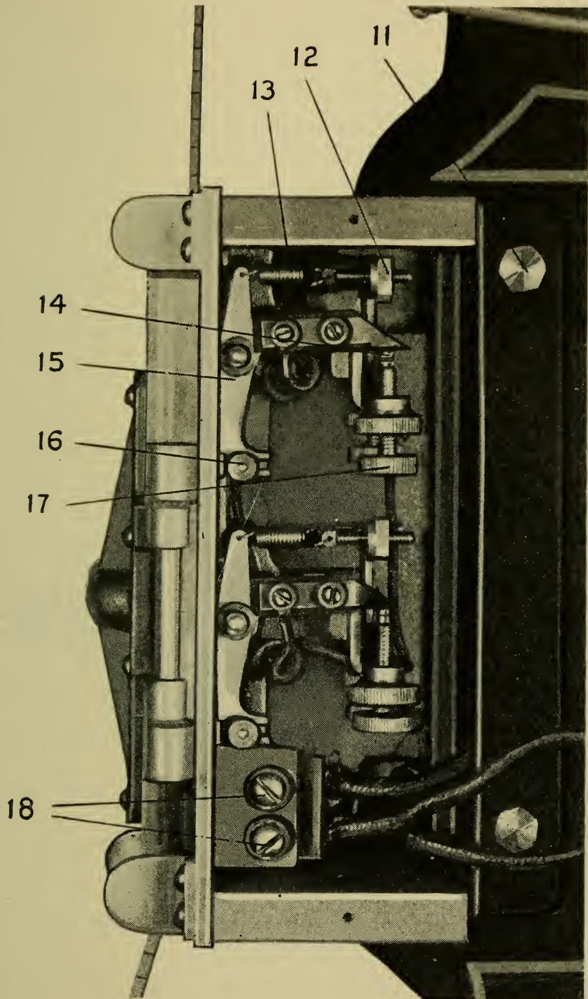


Figure 432.

to one side of the column, and extends to the front of it, though the other cuts make it look as though it was on its face.

At 11, Fig. 432 is the upper of two screws which hold the mechanism of the detector in its casing. 20, Fig. 433, is one of the two guides which keep the film exactly central in the detector box. 21 is one of the two hard-

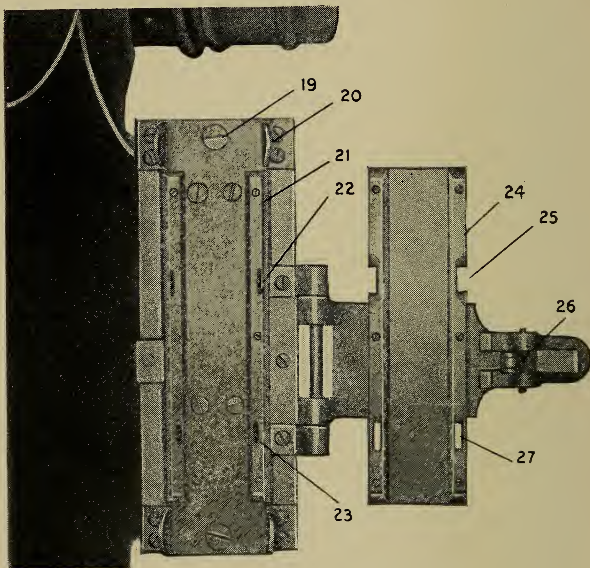


Figure 433.

ened, ground and chromium plated film tracks or "rails" over which the film passes. 22 is one of the two upper detector fingers. These fingers press against the narrow strip of film outside the sprocket holes, opposite opening 25 in the gate. These are called the "outside" detector fingers. Their tips, which ride upon the film, are of genuine rubies, which gave no evidence at all of wear after one year of steady use.

At 23 we see the "inside" detector fingers—one on each side. These ride upon the film, under pressure of spring 13, Fig. 432. They have a longer, flatter surface than do fingers 22, they press upon and ride over the center of the sprocket holes.

The gate rails, 24, Fig. 433, also are hardened and chromium plated. Their faces are ground to an absolutely flat surface. 27 is the holes opposite these lower fingers. The gate latch, 26, Fig. 433, is a substantial lock.

In Fig. 434 we have a view of the mechanism contained in base 8, Fig. 431. 36 is the starting handle. 28 is motor belt. 30 is the brake rod. The brake is set automatically and acts both upon the upper reel and the motor. 31 is a mercury switch, the contacts and mercury being inclosed in a vacuum tube. 33 is a movable armature. 34 is a toggle mechanism.

When the starting handle, 36, Fig 434, is raised, several things happen simultaneously. Toggle 34, Fig. 434, is locked in position. Mercury switch 31, Fig. 434, is tipped so that the mercury runs down and forms an electric circuit between two contacts, which starts the motor and energizes the detector box. Armature 33, Fig. 434, is set into position, ready to tip toggle 34 when it is desired to start. Brakes on motor and upper reel are released, all of which happens practically instantly.

The machine now is in operation, and here is what happens. The mechanism passes film down through the detector box until a point is reached where there is a fault of some sort in the film, or if the device be set to stop at splices, a splice comes along.

The tungsten contact points, 14, Fig. 432, are set by means of adjustment screw 17, Fig. 432, so that they are separated about the thickness of the film when the film is in the box and the gate is closed. So long as the film is whole and intact, this distance will be maintained and the mechanism will continue to function. However,

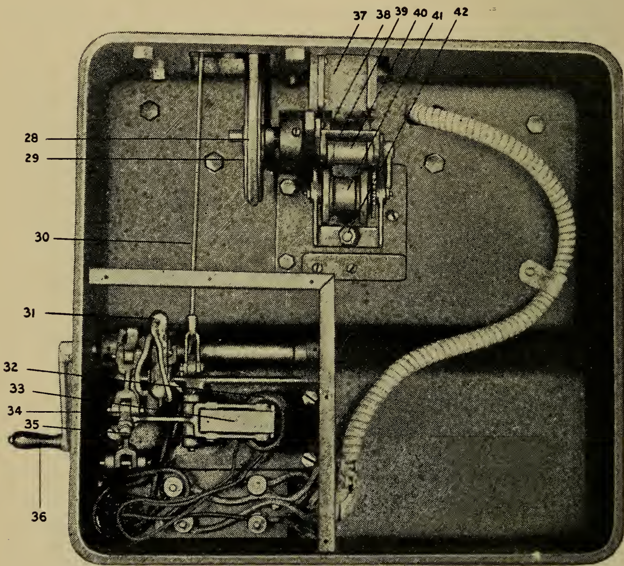


Figure 434.

if a splice passes (stopping for splices which are normal may or may not be arranged for) this distance is altered and the contact between tungsten points 14, Fig. 432, is closed, which automatically causes all the before described processes to be set into action in reverse, and the machine is stopped. Or if there be a fault, such as, for example, a split sprocket hole, or a loose splice edge, then, remembering that fingers 21 and 22 press against the film opposite openings 25 and 27, all Fig. 433, it will readily be understood that the film will "give" a bit as the fault passes, which again operates to close contact points 14, Fig. 432, and stop the machine.

In stopping, the armature 33, Fig. 434, is pulled down when the points close, and the other end of the rocker arm to which it is attached kicks up toggle 34, Fig. 434, mercury switch is tipped back into upright position, the motor circuit thus broken and the brakes applied to both the motor and upper reel. The action is so rapid that the defective spot which caused all this disturbance will usually be found within three or four inches of the bottom of the detector box.

All that may sound a bit complicated, but it really is simple and—it works. I would say that if this machine be handled with reasonable care, it will provide a better inspection than film is ordinarily given in even the best theatres and an inspection far, far better than that ordinarily given by the projectionist.

The trouble with many "Broadway men" is that they imagine they have reached the top, hence stop trying to climb. To the best sort of man there is no top. He always looks up and keeps climbing.

Non-Synchronous Equipment

THE number of non-synchronous sound reproduction and projection devices offered the exhibitor is legion. I have heard the number stated as high as 2,000. They are of all grades, sizes, forms and kinds. No attempt will therefore be made to deal with individual apparatus, save insofar as seems necessary in order to convey a knowledge of the general set-up of such equipment. It is, however, the intent to convey a comprehensive idea of just what such apparatus consists of, and what the exhibitor may hope to accomplish with it.

Non-synchronous apparatus is really a sort of duplex phonograph, of more or less elaborate design. There may be two, three or even four or five turntables, though there appears to be slight advantage in having more than two, or at most three of them. In addition, there is an arrangement for the amplification of sound by means of vacuum tubes, with horns or loud speakers located in the vicinity of the screen. Some of these devices are designed to connect to regular synchronous sound apparatus, to the end that its amplifiers, etcetera, may be used to supply musical accompaniment for silent pictures, using records running at standard phonograph speed and therefore with all the great library of regular phonograph records to draw from, and with the various cueing devices available. Most of the others are so made that this sort of thing may be more less effectively done, or they may be used in theatres where synchronized sound apparatus is not installed.

Some of these devices are housed in a more or less elaborate desk-like piece of furniture, which may or may not have compartments for the storage of records. Others have the turntables mounted on a flat-top table, and still others in a substantial case, very much like a suitcase in form. These latter are portable.

THE ATTENDANT.—Non-synchronous equipment must be in charge of a careful, expert attendant, if the best results are to be had. It is unreasonable to suppose such equipment may be installed, placed in the hands of an inexperienced boy or girl, and good results obtained. He who expects that will suffer disappointment.

It may, however, be said that, given a really good non-synchronous equipment, under the charge of a man or woman of some ability, imagination and energy, it is possible, especially with the cueing services now available to get results in every way decidedly superior to those obtained with the average small orchestra, particularly if the latter be composed of the type of "musician" available to the small town and village exhibitor.

GLARE SPOTS ELIMINATED.—Moreover, there is a very decided advantage in the elimination of the glare spots set up by the orchestra music stand lights, or light reflected from the white sheet music. In considering this very important point we must remember that music is more often than not over-lighted, and the stands placed utterly without regard for the injurious effect either upon the eyes of the audience or upon the picture, the latter by reason of light reflected to the screen from the sheet music.

It may be accepted as fact that if the non-synchronous device be selected with due care as to its excellence and efficiency, and if it be placed under the charge of an attendant who will get the best possible results from it, the equipment may be installed by theatres without the least fear of after-regrets, save only perhaps those having synchronized sound equipment installed who may prefer to use the regular turntable which goes with it.

However, in that latter it will be well to consider the fact that the exhibitor is then restricted to the comparatively limited library of records made for use with that equipment, since those turntables rotate only 33⅓ times to the minute; nor is it possible to increase that speed so that regular phonograph records can be used.

On the other hand, the exhibitor will do well to study the possibility of installing synchronized sound from every angle before purchasing non-synchronous equipment, because there is, beyond any chance for argument, very great advantage in synchronous sound. With it the exhibitor is enabled to bring the best artists right into his theatre in what amounts to a personal appearance. He may, with synchronous equipment, even cause the President of these United States of America, and the King of England to appear before and talk to his home people. He may with that equipment cause the very best operatic singers in all the earth to appear "in person" and actually sing to his people. He is enabled to visualize the news events of the day, and who will presume to question the value of these things to any theatre, be it little or big!

It then becomes a matter of determining whether or no the thing can be made, through the box office, to carry itself financially, and that the wise exhibitor will study very, very carefully, before he makes final decision.

Non-synchronous equipment makes available only the music, songs, etc., recorded upon standard or special phonograph records, but with such equipment there is available to you all the vast libraries of records of the various phonograph record manufacturers, plus the now large and rapidly increasing stock of special records made especially for theatre work in connection with motion pictures.

The exhibitor thus will be able to score his silent pictures with the very best music, or with music by the very best musicians, orchestras and singers of the entire earth, which may be selected and cued by his own theatre staff, or may be had already cued from any one of several services on a weekly payment basis, records supplied.

Among the special records now available are those carrying almost every conceivable sound which would be indicated by the action in a motion picture, except, of course, synchronized speech, singing, etc. For example: a record may be had which contains, in separate recordings, with a clear space between each one, all plainly marked, the barking of dogs of various sorts, as, for example, a small fox terrier; a great, shaggy Newfoundland, with records of various sorts of dogs between, so that when a dog appears in the picture and goes through the motions of barking, by selecting the proper sort of "bark," and carefully timing it, a very realistic effect may be produced. However, if the outfit be in the hands of a careless or unintelligent attendant a very absurd, ridiculous situation might be set up by having the dog bark when the pictured dog very evidently did not bark, or if the wrong record be selected and a fox terrier or wee pomeranian be made to emit a Newfoundland bark, or vice versa.

This is set forth as illustrative of the necessity for a careful, painstaking, intelligent attendant in charge of such devices. Also as indicating the fact that the best effects may only be had by either a careful rehearsal of each production, or by the use of some high grade cueing system.

In addition to the "barking" records, there are available others carrying records of running trains. Trains starting and stopping. Horses galloping or trotting. Soldiers marching, and so on through a rather long list, but it cannot be too strongly emphasized that such records must be used carefully and with good judgment.

RENTAL.—Records may be purchased, or they may be had on a rental basis the same as films. Exhibitors may secure a regular cued record service. These are now being put out by responsible parties, and are being constantly improved. Scoredisc, page 1220, is an example.

METHOD OF HANDLING A SHOW.—The method of handling a show is as follows, with some possible variations: As has been said, there are two or more turntables, which may or may not both run continuously. If a cued service is available, then the attendant has only to follow the cues closely. If not, then, the production having first been rehearsed, and a cue sheet made, records No. 1 and No. 2 are placed on turntables Nos. 1 and 2.

Presuming the first two scenes to be, respectively, a deathbed scene and a circus scene, the record on table No. 1 will be soft, slow music, such as would be appropriate to a scene of that kind. Table No. 2 would carry a record on which is band music of a lively character, such as one would expect to hear in a circus tent.

Record No. 1 is played during the scene, at the end of which the needle is raised from it and the needle simultaneously lowered to record No. 2. The attendant then places record No. 3 on table No. 1, and so on through the production. It is not at all difficult to see what really excellent results might be gotten from such an arrangement, if the equipment be carefully and intelligently handled, or how poor the results might be if the handling be unintelligent and careless.

There are, of course, many possible variations of this procedure, but that is the general plan usually pursued.

It is strongly recommended that before making a purchase, the exhibitor investigate carefully as to the relative merits of various makes and kinds of such outfits. Don't permit the blandishments of a smooth salesman to altogether take the place of your own judgment. If the salesman makes claims as to performance which you believe to be doubtful, oblige him to reduce those statements to writing, and to sign them. Then withhold a portion of the purchase price until those claims have been made good by the apparatus, placing the money in escrow in a bank if required. If the statements made by the salesman are correct, he can have no possible serious objection to such a procedure.

Of course salesmen would not deliberately make a wrong statement, but in their zeal for making a sale they make a lot of claims, some of which they may forget they made when the sale has been completed. If, however, they put them into writing and sign them, there can be no possible argument.

WESTERN ELECTRIC NON-SYNCHRONOUS EQUIPMENT.—This equipment is supplied with the object of furnishing a musical accompaniment to silent pictures, and can also be used to supply music in the theatre at other times, as, for example, during intervals between presentations.

If music is to be reproduced in a theatre, a certain volume will be required, regardless of what may be the source of the reproduction. That is to say, just as much volume will be required if reproduction is being obtained from a commercial phonograph record as if the reproduction were from a synchronized record or a photographic sound record on a film.

This means that, generally speaking, the horn and amplifier equipment for non-synchronous reproduction must be quite similar to what would be used in the same house for synchronized reproduction, and because of this, Western Electric non-synchronous equipments are supplied in the same range of sizes as the synchronous equipments, and are in fact similar to the latter in all respects, except that the non-synchronous turntable takes the place of the disc or film reproducing equipment on the projector. In a large proportion of houses, of course, there are facilities for both synchronous and non-synchronous reproduction, and in this case the same amplifiers and horns are used for all purposes, so that it is merely a matter of throwing a switch to determine whether the input to the amplifiers is derived from the non-synchronous turntable or the reproducing equipment on the projector.

In view of the foregoing it will be seen that the only part of a Western Electric non-synchronous equipment which need be considered in detail is its turntables, which apparatus is shown in Fig. 435.

It consists of two phonograph turntables mounted side by side in a wooden box or cabinet. Each turntable is

Figure 435.

driven by a Victor phonograph motor, and each motor can be controlled separately by means of a switch located beside the turntable which it drives. The speed of each turntable can also be regulated by means of the standard

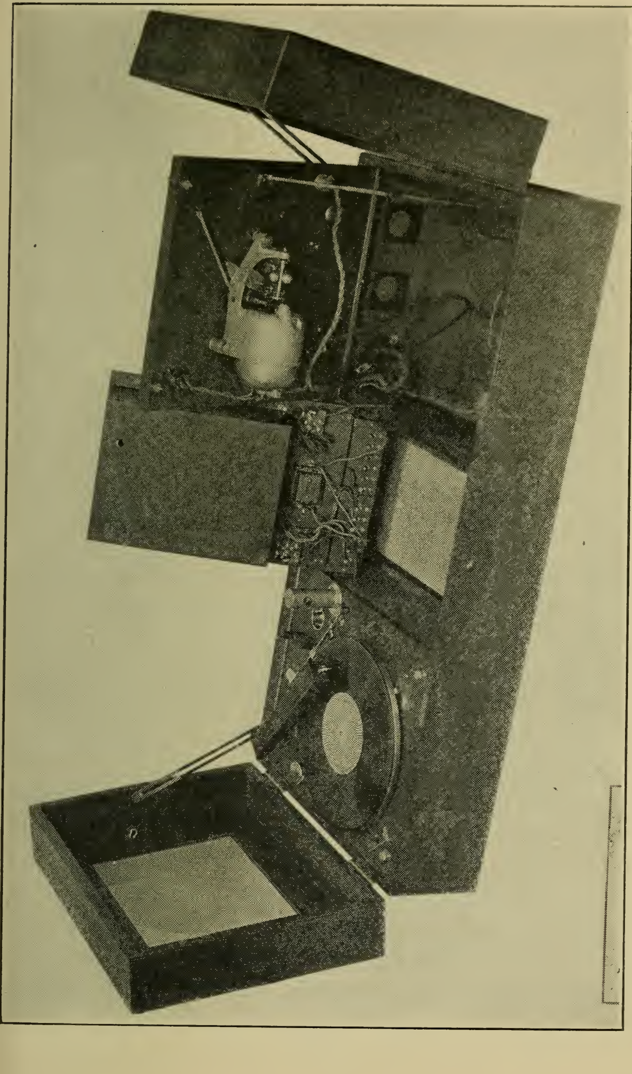


Figure 436.
Western Electric Non-Synchronous outfit shown in Figure 435, with one of its motors and its electric circuit connections displayed.

Victor speed regulator, which is supplied with the motor. The speed used for recording on standard phonograph records is 78 revolutions per minute. It therefore is essential that the speed of each turntable be carefully regulated and maintained at exactly 78 r.p.m., for the same reason that standard speed must be maintained in synchronous disc reproduction, namely, to avoid distortion of the sound by operation at other than the recorded speed. The ordinary phonograph speed indicator is not employed, as it is not sufficiently accurate, and the use of a stroboscope, or revolution counting with a watch, is therefore necessary. **The speed should be carefully regulated and tested once each day.**

The electrical reproducer unit used for pick-up with each turntable is the same as that used in the synchronous disc equipment, the supporting arm and mounting being, of course, somewhat different.

IMPORTANT.—In using an equipment of this type, it is, of course, frequently desirable to select only part of a record for reproduction, which may involve beginning elsewhere than at the start of the record, or finishing the selection before the conclusion of the record, or taking a piece from the middle of the record. To facilitate picking the right points on the record for this purpose, a graduated scale is attached to the reproducer arm. Then by playing the record through and observing the points on the graduated scale at which the desired selection begins and ends, it becomes a simple matter to play this selection whenever desired by moving the reproducer out over the record until the scale indicates that the beginning point of the selection has been reached, and then setting down the needle on the record. A lever is provided which, when depressed, raises the reproducer off the record; when released, lowers it down. This greatly facilitates the use of the scale.

FADER.—For switching from one record to the next, the same means are employed that are used in synchronous reproduction to switch from one projector to the next, namely, the Fader, which will be seen mounted at the middle of the box between the two turntables. The process of running off a program on the non-synchronous equipment is therefore very similar to that required with synchronous equipment. Careful rehearsal is first necessary to determine what selections shall be used, then these selections must be timed with the picture, and the scale readings for the beginning and end of each selection determined, in cases where the whole record is not to be used. Change-over points must also be determined. When these data have been entered on a proper cue sheet, and a rehearsal run, the show is then ready to proceed.

There is one difference between non-synchronous and synchronous reproduction as regards projection speed. Whereas with synchronous reproduction the use of standard speed for the sound reproduction also necessitates the running of the picture at the same speed, and therefore no adjustment in time of the program can be made by altering the speed of projection of the picture, this restriction does not hold with non-synchronous reproduction, because although the turntable speed cannot be varied, that of the projector can be changed and the difference made up by changing the length of the selection used to accompany each scene which is speeded up or slowed down. These and other considerations make it very essential that the person having charge of the non-synchronous reproducing equipment be so located that the screen is always plainly in view, so that the sound reproduction may be intelligently adjusted to the progress of the picture.

GATES NON-SYNC.—After looking over many non-synchronous devices the author has invited the Gates Radio and Supply Company, Quincy, Illinois, to supply a description of their devices, which seem to be fairly typical of such equipment.

This manufacturer puts out two models, each designed to fill a definite purpose. One is known as the Motio-Tone model; the other the Versatile model. We will first look over the

MOTIO-TONE MODEL.—This model consists of three separate parts or units. First is the producing unit, comprised of the pick-up and motor. Second, the reproducing unit, and lastly, the projection unit, which latter is a dynamic cone loud speaker.

The following description is intended to advise you as to just what the equipment consists of.

The producing unit is equipped with two induction type motors and two electro-magnetic pick-ups mounted in what is termed the "True Q Device." This latter is a disc with a series of numbers divided into equal parts, ranging from 0 to 10, covered by an indicator that is attached to the side of the pick-up arm. Its purpose is to enable the attendant to place the pick-up on the record at the exact pre-determined place, which is done by moving the tone arm to the place indicated by the indicator.

The motors are mounted on springs and are supplied with a graduated speed control. Any vibration that might be set up by the mechanical action of the motor would be to a certain extent amplified in the final reproduction, therefore it is necessary to mount the motors on springs, which same act to absorb all vibration. The normal turntable speed is 78 RPM, but the cabinet unit is so constructed that 33⅓ RPM motors may be substituted if desired. The insertion of 33⅓ RPM units is desired by some exhibitors as part equipment. Some desire one 78 RPM unit and one 33⅓ RPM unit. The 33⅓ RPM unit accommodates the records used with synchronous equipment—Vitaphone. For musical scores furnished by the producer, this 33⅓ RPM unit must be used. A movement is now under way to produce these larger slow speed records which will operate on this 33⅓ RPM table, reducing the necessity of changing records so frequently, since such records of course will accommodate a very much more lengthy recording.

FADING PANEL.—There is a Fading Panel, on which is mounted a master switch controlling the A. C. input for the entire equipment. There also is a fading dial which makes it possible to fade from one pick-up to the other, or, in other words, from the record on one turntable to the record on the other. There also are motor control switches by means of which it is possible to use either pick-up separately, or to use them both together if desired.

On the fader panel is a jack into which a microphone may be plugged, if or when it is desired to use one: also there is a light which supplies ample illumination for the attendant to perform his or her duties. The producing unit will be equipped with universal motors, without added cost, if the purchaser prefers them.

The cabinet contains record compartments, one on each side. One of them is shown in open position in Fig. 437. Each of these compartments will accommodate twelve (12) records up to twelve (12) inches in diameter. In addition there is a center compartment in which 200 stock records may be stored.

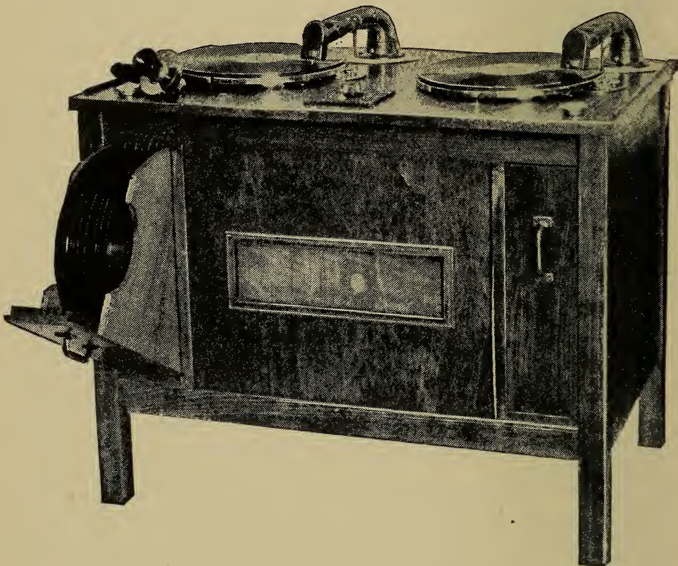


Figure 437.

In this figure we have a view of Motio-Tone 2-disc cabinet, one of the record storage compartments being open.

AMPLIFIER UNIT.—The amplifier unit is so made that it may readily be adapted to synchronous use. In fact, it was and is the purpose of this manufacturer to supply a non-synchronous device which might readily be used for synchronous sound reproduction and projection if desired.

The amplifying unit is of the rack-panel design. It stands forty (40) inches high, is thirty-one (31) inches wide and twenty-two (22) inches deep. It is what is known as a 3-stage unit, the last two stages of amplification being push-pull stages. (See Push-pull, page 1215). The tubes are one UY 227, two UX 226, two UX 250 and two UX 281s.

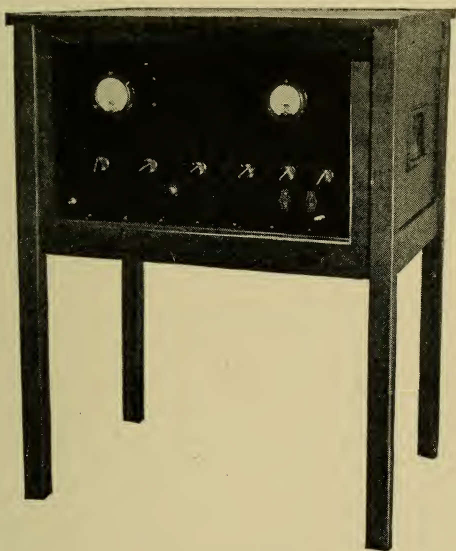


Figure 438.
Amplifying Panel.

OVERLOAD ABILITY.—The manufacturer claims that all the equipment is so made that it has ability to stand from fifty (50) to seventy-five (75) per cent overload temporarily, which will be ample to take care of possible current surge caused by one of the tubes becoming inoperative. Overload thus set up is taken care of by condenser blocks and transformers which have twice the capacity they normally operate at.

The input transformer has a very wide impedance range, which makes it adaptable to use with any high grade commercial pick-up system. The entire amplifying unit has a practically flat curve from thirty (30) to eight thousand (8,000) cycles. The output is designed for use with either high or low impedance speakers, the low impedance secondary being designed in two ways, having an impedance of ten (10) ohms for use with the dynamic air column horns and twenty (20) ohms for use with dynamic cone loud speakers.

A little more clearly in explaining high and low impedances as well as flat curves, etc., we might say that everything works at its very best in a certain cycle or place.

An automobile will derive more miles per gallon at one certain speed than any other speed it may travel. A dynamic cone derives best results with an input of 20 ohms, which is said to be low in impedance. A dynamic horn unit has the same appropriate low impedance input. If we were to pour the entire volume into a dynamic cone or horn unit at, say, 1,000 ohms which is, as will be seen, a great deal higher in impedance, the same effect would be had as if the entire gas tank was poured in the carburetor of the automobile. It would merely choke up and stop. A high impedance unit would be represented by an average commercial air column unit or commercial dynamic cone speaker which has the transformer to lower the impedance to the proper level, self-contained in the speaker. The advantage of the specified impedance of the output for speakers such as 20 ohms, 10 ohms, etc., is: If a certain speaker or reproducer is desired it is imperative that the windings of the reproducer unit match with those of the output device of the amplifier.

If this is not done, distortion and poor reproduction will be had.

It is possible for any output device for any type speaker to be furnished.

CONTROL PANEL.—Examining Fig. 438 we see two meters. The one on the left indicates the current strength or current flow on the first two stages of amplification. The one on the right indicates the current flow on the final stage of amplification.

The volume controls are mounted on the control panel. These are connected across the first and second audio stages. There also are two voltage controls on the control panel. They control the voltage of the first two stages of amplification.

On the instrument panel are three speaker controls by means of which the volume of individual horns or speakers may be regulated. One of these may be utilized if a monitor horn be used.

High frequency cut-off switches are included in the equipment. These are used when a worn or dusty record is used. By their use the frequency in which the resultant noises are worst may be eliminated. Also there is a special input transformer included in the outfit for those who contemplate using synchronized sound in the future, and may wish to use this equipment for that work.

The entire unit has an output of over twenty (20) watts. It will therefore operate from four to six dynamic cone loud speakers. No batteries are used in connection with this equipment.

In speaking of watts output, it is always spoken of as the maximum undistorted output. An amplifier with an undistorted output of 20 watts has the ability, provided acoustic conditions are reasonably good, to fill easily a 3,000 seat theatre with undistorted service. An amplifier operating with the volume control half off would be, practically speaking, operating at 10 watts output, hence would not be taxed to its limit. The same would be true of a 100-watt light bulb of the 110-volt type if 55 volts were put into it. It would be operating at 50 watts, or half capacity.

REPRODUCING UNIT.—The reproducing unit, or rather the sound projection unit, is of the dynamic cone variety, using an eleven (11) inch cone. The field is excited by a one hundred (100) volt D. C. source supplied by a UX-280 tube working as a rectifier. This tube is mounted in the unit. The unit will respond to or from frequencies below audibility to those above audibility with equal uniformity. The reproducing unit is characterized by the elimination of false harmonic reproduction.

NOTE.—The claims made in this description are manufacturer's claims. I have no reason to doubt their correctness, but of course cannot stand sponsor for them. —The Author.

The unit is mounted on an easel which stands five (5) feet high and is twenty-six (26) inches wide. It is shown in figure. The easel acts as a baffle to the cone, which is rigidly attached to a support at the rear to the easel, but not to the baffle itself. If two cone units are used, they are connected in parallel. If more than two are used, then a special transformer is supplied, its capacity depending upon the number of units to be used.

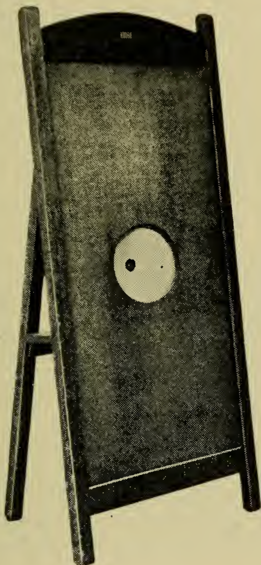


Figure 439.

VERSATILE MODEL.—The Versatile model has the same reproducing unit supplied with the Motio-Tone model. The motors are the same type, as also are the pick-ups, fading panel, record drawers, etcetera, except that the amplifying unit is self contained. It is a four-tube, heavily constructed unit having two stages of amplification. The final stage uses a UX-250 or a UX-210 tube, at the option of the user.

This equipment is entirely A. C. operated, from the power lines. It has specially designed transformers

Figure 440.

RCA Photophone Non-Synchronous Turntable Equipment.

RCA Photophone, Inc., manufactures a non-synchronous twin turntable which is used in conjunction with the regular RCA Photophone amplifier and loudspeaker system to reproduce ordinary 78 revolutions-per-minute phonograph records. This equipment consists essentially of a twin turntable, two magnetic pick-ups and necessary apparatus for changing from one disc to the other. Each turntable is equipped with an induction disc motor which operates from the 110-volt, 60-cycle power line, drawing negligible current. On each RCA Photophone amplifier there is included a special jack labeled "Phonograph Pick-up," and the output from the non-synchronous turntable is fed into this jack.

With this system it is possible for a theatre to score a picture which was not originally supplied with a synchronized score on film or disc. Special effects may also be reproduced by this system, employing appropriate recordings. The RCA Photophone turntable is equipped with a volume control which is calibrated so that a cue sheet may be arranged, and with a fader for transferring from one disc to the other.

which, together with a uniquely designed first stage amplification, gives an amplitude of volume claimed to be greater than is supplied by average two-stage amplifying units of this variety. Like the Motio-Tone, this equipment is designed to withstand an overload of from fifty (50) to seventy-five (75) per cent for a reasonable length of time.

This equipment is supplied in two classes, namely Class A and Class B. Class A has two 11-foot air column horns, built very compactly. It is designed for use where space for horn installation is very limited. The horns have a bell twenty (20) by twenty-four (24) inches. The air column is, as before set forth, eleven feet in length. This unit has capacity for auditoriums seating from 600 to 800, with reserve volume available.

Class B installation has two much larger horns, the bells (openings) being 38x40 inches. The air column is only eight (8) feet nine (9) inches, but the cubical content of the air column is nevertheless much greater than that of the Class A installation horns. The reproducers are very similar to those used by Vitaphone.

INSTALLATION.—Both models (Motio-Tone and Versatile) have everything plainly marked and blueprints are supplied for installation.

Don't try to impress the service engineer with the idea that you know a whole lot. He will be able to size your knowledge up by results. Your job, in so far as concerns the service engineer, is to pump his well of knowledge dry.

Push-Pull Amplification

TO many the expression "push-pull" as applied to amplification is a dense mystery. In order to explain this process, let's think back for a moment to the fundamental idea of amplifier action. It will be recalled that in a vacuum tube amplifier the essential feature of its action is that if we change the voltage on the grid there will be a corresponding change in the current flowing through the plate circuit of the tube. Since the grid draws practically no current and the voltage change on it need only be of the order of a few volts, whereas the plate may be operated with 100 volts or more and may draw several milliamperes, obviously we have here a means of using an infinitesimal amount of power to control a much larger amount, in fact, practically as large as we please. In other words, whatever frequency change or wave-form we apply in the shape of grid voltage, we obtain in the plate circuit a greatly magnified copy of this frequency change or wave-form.

However, this device, like everything else, must somewhere or somehow have a limit to its capabilities, and its particular limitation occurs in regard to the amount of electrical magnification it will afford, or putting it another way, if we need a certain amount of magnification, it may be possible to get it all with one tube, but the magnification may not be accurate, and the output from the plate may not be a true copy of the input to the grid.

Why does this happen? Simply because the change in the plate current for each volt that the grid potential changes, which is, of course, a measure of the degree of magnification obtained, is not always the same, unless the changes in the grid potential are relatively moderate. For example, suppose we had an amplifier where the normal plate current was 10 mils. Then suppose we put on the grid an alternating voltage varying between +1 volt and —1 volt, and that this caused the plate current to vary correspondingly between 12 mils and 8 mils, giving therefore an A. C. plate output varying between +2 mils and —2 mils. The change in the plate current is in this case proportional to the change in the grid potential and we are getting undistorted amplification. But suppose we try to get more output by increasing our A. C. voltage on the grid to +3 volts and —3 volts, and suppose we now find that the plate current varies correspondingly between 17 mils and 5 mils, so that the A. C. plate output varies between +7 mils and —5 mils, whereas it should really be +6 and —6 mils. The proportion is no longer maintained; the positive half of the wave gets too much amplification and the negative half gets too little. The tube is said to be overloaded. This is one form of what is called distortion, and is noticeable as causing a harsh, noisy quality in the reproduced sound. The necessity of avoiding this leads to the use of several stages of amplification, since each stage can handle only a certain part of the total increase or magnification required.

But to a certain extent we can eat our amplification cake and have it as well, if we notice that, as just mentioned, in the overloaded tube there is too much amplification on the positive half of the grid voltage wave and too little on the negative half. Suppose we take two tubes and connect the grid of the first tube to one end of the secondary winding of an input transformer, and the grid of the second tube to the other end of this winding. Then, obviously, if there is A. C. flowing in the transformer winding, a half wave which appears as positive to one grid will appear as negative to the other, and vice versa. You might say that one grid is pushing while the other is pulling, and they do this alternately. Hence this is called push-pull amplification. With this arrangement, even if a half wave gets too little amplification in the tube where it makes the grid negative, it will at the same time be getting too much amplification in the other tube where it makes the grid positive. The plate currents from both tubes combine their action in the plate circuit, and the result is that the distortion caused by one counterbalances that caused by the other, making the total output just about right. That is the principle of push-pull amplification.

Of course, even this principle has its limit; if the two tubes are worked too hard, a point will be reached at which the distortion introduced on the negative half wave no longer balances that on the positive half wave, and then the total current will be distorted. However, as a general rule it may be said that two tubes working in push-pull will give about three times as much undistorted output as one tube, or 50 per cent more than they would give if simply connected in parallel.

If the manager says the screen is all right and you know it is not, get a sheet of white cardboard such as business cards are made from, hang it or support it in the middle of the screen after the show has closed, project a picture and invite the manager to look at the screen.

Scoredisc System of Cueing

THE Scoredisc Service Corporation of New York City has a system for cueing productions which is very practical in its workings. The "Scoredisc" consists of two sheets of cardboard labelled "A" and "B," one being designed to go on either of the two main turntables of any non-synchronous sound reproducer.

These paper discs have printed, around their periphery, cues numbered consecutively from one up in odd numbers on one disc and consecutively from two up in even numbers on the other disc, the two combined being designed to cover an entire production.

In Fig. 441 you have a view of one of these paper discs. You will observe a great many slots shaped something like the Indian's Pipe of Peace. You will also observe that these slots are of various lengths, the slot-length determining the length of time that particular setting of the needle will play. To use these discs, as has been said, one is placed on either of the two turntables and the needle of one turn-table is placed at the bent end of the slot of cue No. 1. When the production starts, the disc is set rotating. The paper disc remains stationary and the disc is played until the needle, by the grooves of the record, has been moved to the end of that slot, whereupon the needle of the other turntable is lowered into the same position of the slot corresponding to cue No. 2, and so on throughout the entire production.

Of course, this requires a different record for each slot, and the supplying of these records is a part of the service provided by the Scoredisc Service Corporation, for which, of course, a weekly charge is made. The Scoredisc Service Corporation sends, at the outset, a library of more than one thousand selections on records,

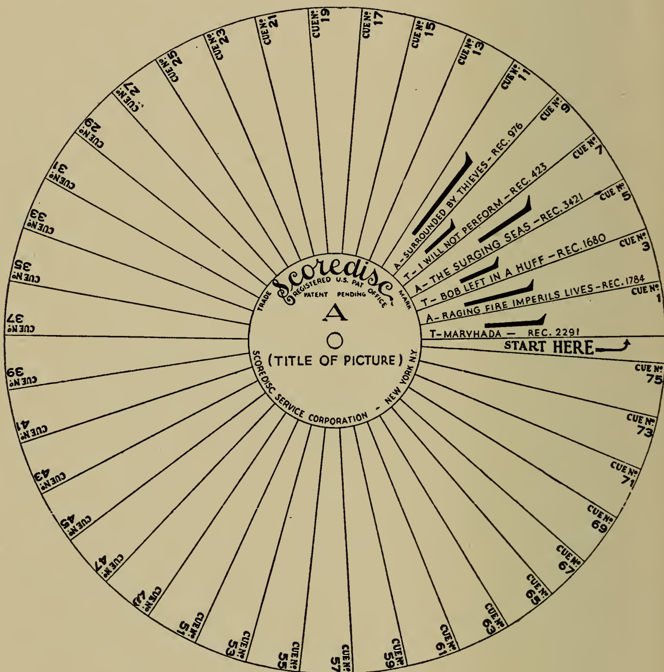


Figure 441.

to which are added such special numbers as may be necessary from time to time. Each one of these records carries a serial number, and when, with any particular production, records are necessary other than those in the library of the exhibitor, they are supplied together with the Scoredisc for that particular production. In addition to that, any records that are worn out are replaced without cost.

The particular method is as follows: The exhibitor furnishes to the Scoredisc Service Corporation a list of the productions that he is to play, ten days in advance of the time of playing. The Scoredisc Company sends, in advance of the play date of each picture, first, a printed list of all the records from his own library which are to be used in each production. Such a list is shown below. In addition to that, the Corporation sends any records that the exhibitor may require in addition to those records then in his library. The Scoredisc Service Corporation retain in their files a list of all the records in the library of the exhibitor, so that they are in a position to know exactly what else is required. Of course, Scorediscs (the paper discs before described), are supplied for each production the exhibitor books, released by National Distributing Organizations.

This system appears to be entirely practical and efficient. It has our commendation.

SUNSET PASS

PARAMOUNT

The following record numbers used for this production:

Record No. 697—Cue No. 1.
Record No. 246—Cue No. 2.
Record No. 468—Cue Nos. 3–31.
Record No. 430—Cue Nos. 4–28.
Record No. 255—Cue No. 5.
Record No. 445—Cue No. 6.
Record No. 325—Cue Nos. 7–30.
Record No. 304—Cue No. 8.
Record No. 809—Cue Nos. 9–17.

Record No. 110—Cue No. 10.
Record No. 146—Cue No. 11.
Record No. 544—Cue No. 12.
Record No. 627—Cue No. 13.
Record No. 208—Cue No. 14.
Record No. 411—Cue No. 15.
Record No. 597—Cue No. 16.
Record No. 533—Cue No. 18.
Record No. 594—Cue No. 19.
Record No. 470—Cue Nos. 20–22.
Record No. 159—Cue No. 23.
Record No. 659—Cue Nos. 24–26–33.
Record No. 465—Cue No. 25.
Record No. 255—Cue No. 27.
Record No. 188—Cue No. 29.
Record No. 135—Cue No. 31.
Record No. 302—Cue No. 32.

The Projection Room

THE advent of sound has necessitated a considerable change in the theatre projection room in order to accommodate the new equipment. More space is required, of course, and additional rooms adjacent to the projection room are highly desirable.

It is not good business to attempt to jam equipment of this sort into space usually none too generous before it came. It may possibly be done, but as has been pointed out many times, it is the poorest kind of business policy to force men engaged in so important a work as motion picture projection, and especially motion picture projection with sound reproduction and projection added, into crowded, uncomfortable quarters.

The management which attempts to "save" the price of making the enlargements necessary to properly accommodate sound equipment, is more than likely to lose ten, or even a hundred times the supposed "saving" at the box office because of the resultant lack of that touch of excellence which marks the dividing line between high grade and mediocre.

Men in crowded, and therefore uncomfortable quarters, feel little encouragement to strive to excel. That is natural. If the management does not care enough about us and our work to provide a decent place in which to work, why should we make the extra effort necessary to put on the best possible picture and sound production? is about the way the average projectionist feels about it. As a matter of fact, I have had that very idea presented to me many, many times by men with whom I have remonstrated concerning their mediocre work.

The wise theatre management will provide ample space in the projection room, and reasonable accommodations for the health and comfort of the men who must work therein, and then will demand results in keeping with the equipment and accommodations provided.

He will have the **right to demand!** But under such conditions the very fact that he must demand would stamp the man who did not respond to those conditions as unfit to be in a projection room. I think you will all agree, without reservation, to that.

In the matter of space, the main projection room should, and, to be of suitable dimensions, must have sufficient front-to-back depth to allow of a full three (3) foot passageway the full length of the room, back of all projection equipment. That is a minimum. It may be more, but must be no less.

Of course, if amplifiers or other equipment are to be placed against the rear wall, this means that there must be three full feet between the rear of the projectors and it, and by that it is meant between the controls on the rear of the lamphouses and the controls, if any, on the face of the equipment against the rear wall. The three-foot passage must be entirely free and clear of all obstruction.

As to projection room width, there is a growing tendency to space the projectors somewhat further apart than formerly. Some have advocated as much as five feet between lens centers, but that the author regards as extreme, except for very long projection distances. Many advocate as much as four to four feet six inches, which is all right on long projection distances, but too much unless the distance be at least in excess of one hundred feet.

That is a matter for very careful consideration. Before deciding, the architect should lay out the light beam at various spacing distances and ascertain exactly what the distortion will be. The spacing should be as much as can be had without objectionable distortion, up to five feet, but before deciding on maximum distances it will be well that the lens maker be consulted as to whether the lenses will have sufficient depth of focus to take care of the situation.

On the whole, I believe this whole subject may best be dealt with by quoting the report made by the Projection Committee of the Society of Motion Picture Engineers, made at its 1929 spring meeting. It covers the subject of the projection room with fair completeness as to the fundamental requirements of an acceptable room.

Your big job—the very biggest one you have—is to sell projection to your manager. And, believe you me, brother, with some of them it will take a lot of selling.

The Theatre Projection Room of Today

THE motion picture is a fusion of the arts and the exact sciences. In the highly specialized field of projection, while art is far from absent, the exact sciences are dominant. These exact sciences are expressed by laws which have existed, unchanged, since time began, and will exist, unchangeable, when time shall end. They are fundamental, physical laws of the universe. We may attempt to disregard them, we may even deny their existence, or laugh at them as being the brainstorm of "some impractical scientist," but they are not changed thereby one iota.

No scientist ever could or did lay down a law. He merely enunciates these fundamental laws of the universe, which we may abide by or violate at our own discretion, but the consequences of our action are absolutely certain and beyond all human power to modify or evade.

Let the architect and the theatre owner consider well these facts when the matter of projection suite location and design is before them. They cannot violate fixed laws and obtain the maximum in projection results.

After considerable thought I have decided to incorporate in this work the report made by the Society of Motion Picture Engineers Projection Committee at its 1929 spring meeting as the best data available on the fundamental requirements of the modern theatre projection room, because, while it is a first report and neither perfect nor complete, still it is the best thing now available on the subject.

The formulas used therein were worked out by that brilliant motion picture projectionist, Chauncey Green of Minneapolis, Minnesota.

This report has been considered and has been adopted by that body of conscientious, capable engineers. It will be, in due time, added to, but as it now stands it offers suggestions which have been approved and formulas which the architect may use and which will be for him a guard against error in the matters covered.

The architect may disregard these laws and suggestions, true; but if he does, then the quality of reproduction, either optical or acoustical or both, must and will inevitably be injured and lowered.

A REPORT
OF
THE PROJECTION COMMITTEE
OF
THE SOCIETY OF MOTION PICTURE ENGINEERS

F. H. Richardson, *Chairman.*

Arthur H. Gray. Lester B. Isaac.
Chauncey L. Greene. J. H. Kurlander.
Herbert Griffin. Harry Rubin.
Mark S. Swaab.

TO THE SOCIETY
AT THE SPRING CONVENTION
MAY, 1929

To the President and members of the Society of Motion Picture Engineers in convention assembled:

Gentlemen: The Society has seen fit to give official recognition to the importance of motion picture projection and the motion picture projectionist by the appointment of a standing committee on projection.

After due deliberation, and after consultation with the various members of the committee, it was decided to concentrate our first efforts upon the compilation of a statement of what constitutes the fundamental requirements of the modern projection room. Our decision in this matter was based upon the fact that, while it is true some matter has appeared in the trade press and considerable appears in the Bluebook of Projection, there is not available to the architect, except at the expense of a great deal of time and trouble to himself, a complete, correlated and comprehensive, yet concise, treatise on the requirements of the modern projection room, and the fundamental requirements which must be satisfied if results which can be adjudged acceptable, according to modern standards, are to be obtained and (what is of equal importance and difficulty) maintained.

And, gentlemen, there is great need for such a treatise. The lack of any authoritative standards to which architects may refer has resulted in a very large number of poorly planned projection rooms, and a still greater number which are hopelessly inadequate for modern motion picture and sound picture projection.

Your committee therefore selected as the subject for its first report **The Fundamental Requirements of the Modern Theatre Projection Room,** the various items of which will be set forth in their order, together with such recommendations as may seem proper.

LOCATION.—It is essential to good projection that the projection room location be such that there will be no objectionable distortion of the screen image due to the projection angle being excessive, and furthermore it is essential that the projection distance and picture size be so related as to require the use of a lens of such focal length as to combine critical definition over the entire field with reasonable optical efficiency. Your committee realizes that the great variation in theatre auditorium conditions demands considerable elasticity in the matter of projection room location, and therefore recommends:

1. That the relationship between picture size and projection distance be such as to require a projection lens of not less than four and one-half inches nor more than seven and one-half inches equivalent focus.

2. That within this range of lenses the projection angle be as nearly zero as is practicable, and in no case to exceed seventeen degrees.

The recommendation as to the equivalent focus of the projection lens is based upon the observations of the members of your committee. The decision in the matter of the limiting angle was reached through a mathematical analysis of the situation. Let us refer to Fig. 442 in which O is the optical center of the projection lens, θ is the projection angle, $\propto$ the vertical angle of divergency of the light beam, AC the height of the projected picture, and BD the height of an undistorted picture projected the same distance (OE) by the same lens.

Realizing that for a given projection angle the distortion would be more serious with short focus lenses

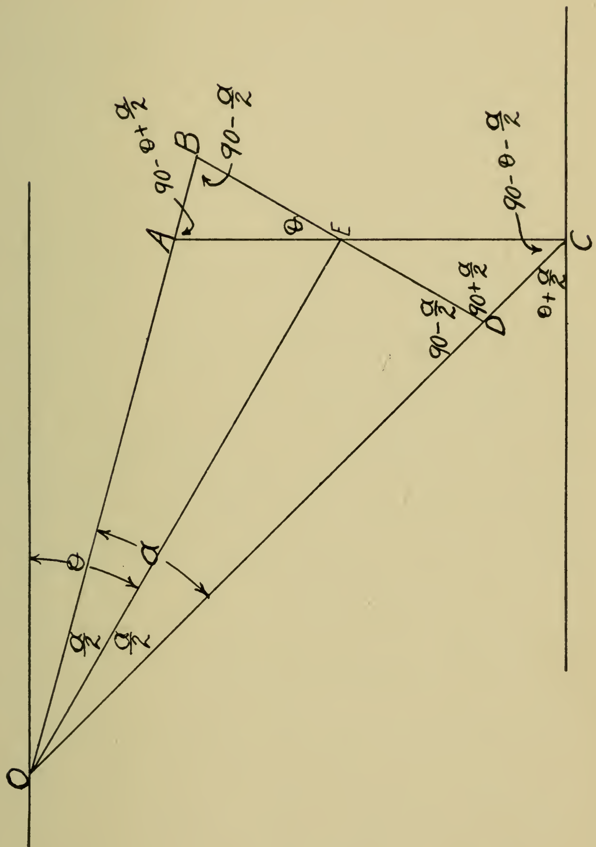

A
B
C
D
E
O
$90-\theta+\frac{a}{2}$
$90-\frac{a}{2}$
$90-\theta-\frac{a}{2}$
θ
$90+\frac{a}{2}$
$90-\frac{a}{2}$
$\theta+\frac{a}{2}$
θ
a
$\frac{a}{2}$
$\frac{a}{2}$

Figure 442.

than with those of long equivalent focus, your committee sought to express the increase in height of the projected picture due to the projection angle in terms of this angle and the angle of divergency of the light beam, that is to express the ratio AC : BD as a function of θ and $\propto$.

$$\frac{AC}{BD}=\frac{AE+EC}{BE+ED}$$

Now $AE : \sin\frac{\propto}{2} :: OE : \sin\left(90+\theta-\frac{\propto}{2}\right)$

Therefore $AE=OE\sin\frac{\propto}{2}\div\sin\left(90+\theta-\frac{\propto}{2}\right)$

And $EC : \sin\frac{\propto}{2} :: OE : \sin\left(90-\theta-\frac{\propto}{2}\right)$

Therefore $EC=OE\sin\frac{\propto}{2}\div\sin\left(90-\theta-\frac{\propto}{2}\right)$

Also $BE+ED=2OE\tan\frac{\propto}{2}$

Then $$\frac{AC}{BD}=\frac{\dfrac{OE\sin\frac{\propto}{2}}{\sin\left(90+\theta-\frac{\propto}{2}\right)}+\dfrac{OE\sin\frac{\propto}{2}}{\sin\left(90-\theta-\frac{\propto}{2}\right)}}{2\,OE\tan\frac{\propto}{2}}$$

$$=\frac{OE\sin\frac{\propto}{2}}{2\,OE\tan\frac{\propto}{2}\sin\left(90+\theta-\frac{\propto}{2}\right)}+\frac{OE\sin\frac{\propto}{2}}{2\,OE\tan\frac{\propto}{2}\sin\left(90-\theta-\frac{\propto}{2}\right)}$$

$$=\frac{\cos\frac{\propto}{2}}{2\sin 90+\left(\theta-\frac{\propto}{2}\right)}+\frac{\cos\frac{\propto}{2}}{2\sin 90-\left(\theta+\frac{\propto}{2}\right)}$$

$$=\frac{\cos\frac{\propto}{2}}{2\cos\left(\theta+\frac{\propto}{2}\right)}+\frac{\cos\frac{\propto}{2}}{2\cos\left(\theta-\frac{\propto}{2}\right)}$$

$$\frac{AC}{BD} = \frac{\cos\frac{\propto}{2}}{2\left(\cos\theta\cos\frac{\propto}{2} + \sin\theta\sin\frac{\propto}{2}\right)}$$

$$+ \frac{\cos\frac{\propto}{2}}{2\left(\cos\theta\cos\frac{\propto}{2} - \sin\theta\sin\frac{\propto}{2}\right)}$$

$$= \frac{\cos\theta\cos^2\frac{\propto}{2}}{\cos^2\theta\cos^2\frac{\propto}{2} - \sin^2\theta\sin^2\frac{\propto}{2}}$$

Inverting and simplifying

$$\frac{BD}{AC} = \cos\theta - \frac{\sin^2\theta}{\cos\theta}\tan^2\frac{\propto}{2}$$

Now the maximum permissible amount of distortion is a matter on which there seems to be considerable range of opinion. Your committee feels that in recommending 5 per cent at the maximum permissible increase in picture height it is erring on the side of laxity rather than rigidity, and is particularly anxious to hear discussion of this matter by the Society.

Proceeding for the moment on the basis of 5 per cent:

$$\cos\theta - \frac{\sin^2\theta}{\cos\theta}\tan^2\frac{\propto}{2} = 0.9524$$

and

$$\cos^2\theta - \sin^2\theta\tan^2\frac{\propto}{2} = 0.9524\cos\theta$$

$$\cos^2\theta - \tan^2\frac{\propto}{2} + \cos^2\theta\tan^2\frac{\propto}{2} = 0.9524\cos\theta$$

$$\sec^2\frac{\propto}{2}\cos^2\theta - 0.9524\cos\theta - \tan^2\frac{\propto}{2} = 0$$

This puts the equation in the quadratic form, and the solution for cosine θ is of course

$$\cos\theta = \frac{0.9524 \pm \sqrt{0.9524^2 + 4\sec^2\frac{\propto}{2}\tan^2\frac{\propto}{2}}}{2\sec^2\frac{\propto}{2}}$$

Taking account of the minus sign before the $\sqrt{}$ results in imaginary values so only the positive sign will be considered. Calculations (by 10″ slide rule) are tabulated below thru the range of objective lenses recommended in this report.

Lens E.F.	BD	$\tan\frac{\alpha}{2}$	$\tan^2\frac{\alpha}{2}$	$\sec^2\frac{\alpha}{2}$	$2\sec^2\frac{\alpha}{2}$	$4\sec^2\frac{\alpha}{2}\tan^2\frac{\alpha}{2}$
4	17.0	0.085	0.00722	1.00722	2.01444	0.0290
5	13.6	0.068	0.00463	1.00463	2.00926	0.0186
6	11.3	0.0565	0.00319	1.00319	2.00638	0.01285
7	9.7	0.0485	0.00235	1.00235	2.00470	0.00942
8	8.5	0.0425	0.00180	1.00180	2.00360	0.00721

E.F.	Log Cos θ	θ
4	9.97924−10	17° 35′
5	9.97901−10	17° 40′
6	9.97893−10	17° 42′
7	9.97870−10	17° 44′
8	9.97887−10	17° 44′+

Thus it becomes apparent that, through the range of focal lengths recommended, the percentage of increase in picture height is practically influenced only by the projection angle, the percentage being approximately equal to the "secant minus one" of the projection angle. The present standards of the Society set the maximum projection angle at 12°, corresponding to an increase in picture height of about 2.5 per cent. Thus we see that the distortion has doubled for a 40 per cent increase in projection angle, and it becomes exceedingly apparent that it is a serious thing to add even as much as two degrees to the projection angle when designing a theatre, that it should never be done except for the most urgent reasons, and never merely to obtain architectural symmetry in a part of the theatre which the audience seldom sees.

The sidewise location of the projection equipment should be so graded as to favor those projectors which have to produce the most sharply defined images. This consideration would place the motion picture projectors as closely as possible to the center line, but there is the additional consideration of the increasing practice of simultaneous operation of stereopticon, effect projector and motion picture projector to secure special and very beautiful effects which lose much of their beauty if the images are not very closely matched. These considerations have led your committee to classify its recommendations regarding transverse location of equipment as follows:

For the installation of either two or three motion picture projectors, stereo, and effect projector, with or without spot lamps and flood projector, we recommend that the axis of projection of the motion picture projector nearest the stereo be at right angles to the horizontal axis of the screen.

For installation of three motion picture projectors with or without spot lamps we recommend that the axis of projection of the center projector be at right angles to the horizontal axis of the screen.

For installations comprising two motion picture projectors only (or with the addition of spot lamps) we recommend that their axes of projection make equal and opposite angles with the horizontal axis of the screen.

In certain special cases it will be highly desirable to locate the projection room in (not on) the front of the balcony. In such cases a careful check of the balcony construction should be made to insure that there will be no shifting of the axis of projection as the balcony fills and empties. Ventilation of a projection room so located becomes more of a problem than in the case of the more common locations, but it is of much greater importance. This will be treated later.

DIMENSIONS (size of room).—The size of the room may vary rather widely, according to the amount of equipment it is intended to install, but in width the wise exhibitor will make ample allowance for possible additional equipment. That is just as important as it is to install wiring having capacity sufficiently in excess of immediate needs in order to take care of demands which may be made in the future. It is an expensive thing to rebuild the room, or to tear out the wiring to install larger wires, but at the time of construction neither a bit of added space or somewhat larger wires present any very serious additional outlay.

In the matter of front to back depth there must be sufficient space to leave at least a thirty-six (36) inch passageway clear of everything between the lamphouse controls and whatever may be against the real wall. That amount of space is imperatively necessary to a good condition. The necessary depth may be ascertained by the architect by taking the over-all projector length of the modern projector, setting in horizontal position at sixty-three inches, adding one foot to that measurement, or eighteen inches if the projection angle will be a heavy one, and thirty-six inches plus the depth of whatever equipment it may be intended to place back of the projectors against the rear wall. In fact, it is best to allow three feet for that latter, whether there is present intent to install anything there or not, which would make a total of five feet three inches plus six feet equals eleven feet three inches as the minimum front to back depth.

In the matter of ceiling, seven and one-half feet should be the absolute, irreducible minimum. In excess of that the more the better.

As to width, that is a mooted question but there must, for the best results, be ample space between projector, both motion picture and other sorts, to permit of free movement. Where the projection distance and picture size is such that a sharp picture may be obtained all over the screen with a four and one-half foot spacing lens center to lens center of motion picture projectors, that distance should be the minimum. However, conditions may be such that this would be impractical, but under any condition there must be no less than a three and one-half foot spacing lens center to lens center. In fact, this may be the rule for all but the motion picture projectors.

Of course space must be allowed for the amplifying panel, etc., and this should be done in future whether sound is to be immediately installed or not.

This is not designed to be anything more than a general discussion of dimensions. Your committee hopes, in the future, to take that item up in more complete form.

CONSTRUCTION.—Your committee conceives the fundamental requirements of projection room construction to be:

(a) The room must be thoroughly fireproof.

(b) It must be as nearly as possible soundproof, because of the fact that in addition to the unavoidable noise incident to machinery in operation we now have added the necessary conversation between the augmented projection staff, the additional noise created by certain types of sound equipment, and rising above this the output of the monitor horn.

(c) The material should have as low specific heat as possible to prevent its becoming a "storage reservoir" for heat.

(d) In some cases the weight will have to be considered if the building structure supporting the projection room is not amply strong. In this connection your committee desires, without recommendation, to point out that for wall construction hollow tile eight inches or more in thickness set in rich mortar strongly tempered with cement, and covered with a smooth hard finish plaster, fulfills all of the above requirements better than any other material.

The floor slab should support the projection equipment without the slightest vibration, and be of a material which will not wear away and form dirt or dust. We therefore recommend that the floor slab be of concrete of approved mixture, not less than six inches thick, covered with an approved top dressing of cement and covered with battleship linoleum or rubber tile firmly cemented to the floor slab. This linoleum or tile should be laid after all plastering, painting, wiring, etcetera, has been completed, but before any of the projection equipment has been installed. Before the projection equipment is installed the linoleum should be thoroughly cleaned and waxed to prevent it absorbing oil from the machinery. Incalculable damage has been done to projection machinery and to sound film by the fine dust rising from uncovered projection room floors; such stone floors belong to the stone age, and have no place in the modern projection room. Aside from their injurious effect upon equipment, they have the effect of unduly fatiguing those who must stand constantly upon them, thus reducing their alertness and lowering their efficiency, two things which no theatre can afford to have happen to its projection staff.

CONDUITS, OUTLETS AND ANCHORS.—In the modern projection room there is the necessity for so many electrical circuits that it is both unsightly and highly impractical to run the conduits on the surface. They must be built into the walls, floor and ceiling. It is also essential that all electrical outlet boxes, ventilation ducts, anchor bolts, etcetera, be exactly located prior to the construction of the room, and that the faces of all outlets be located flush with the surface except in special cases where there is good reason for doing otherwise.

REWIND ROOM.—This room is for storing, rewinding, inspecting, repairing and assembling film. It should open directly into the main projection room, and if possible into the screening room as well. Every possible precaution in design, finish, equipment and ventilation to make this room clean and dust-free is justifiable when one considers the delicate nature of the sound track on modern sound film. Size will vary with conditions, but your committee regards ten feet by twelve feet as representing the minimum acceptable dimensions unless storage cabinets for film and records are built into the walls of the room.

BATTERY ROOM.—If battery operated sound synchronizing equipment is to be installed there must be a throughly ventilated room sufficiently large to accommodate these batteries and their charging equipment conveniently adjacent to the main projection room. Batteries, in charging, give off gas and vapors which are inflammable and have a corrosive action on human tissues and on most metals. Hence the absolute necessity for ventilation. This room should be at least six feet wide by eight feet long, with suitable shelving to receive the batteries.

MOTOR GENERATOR ROOM.—In modern practice it is fundamentally essential that there be a well ventilated room adjacent to the main projection room for housing the resistance units or the motor generator, whichever be employed. Here, as in the projection room, construction should be fireproof, and all conduits, et cetera, should be built into the walls, floor and ceiling, not run on the surface. Size will vary greatly with the type of installation. The fundamental requirement is that ample space and light be provided around each unit. In certain types of sound equipment a motor generator unit replaces almost all of the storage batteries. In such cases more motor generator space must be provided, but the battery room can be reduced to a ventilated cabinet in the motor generator room.

WASH ROOM.—It is fundamentally essential, regardless of the type, class or size of theatre, that, adjacent to, and opening directly into, the main projection room there be a room of suitable dimensions equipped with wash basin and toilet, with running water. To this equipment many progressive exhibitors have added a shower bath which, while not a fundamental necessity, is most excellent dividend paying equipment, especially in warmer climates. The wash room is an absolute necessity now that sound film has arrived, because dirty, oily hands are mortal enemies to sound film or disc records.

OBSERVATION PORTS AND FIRE SHUTTERS.—The size and position of all ports are matters governed largely by local conditions. The main factors to be considered are type of equipment, size of theatre and projection angle. Fundamentally port requirements are very simple. The projection port should permit the projection of an image to any part of the theatre required of that particular projector. In the case of the spot-lamps, flood-lights, stereopticon, and effect projectors, and at least one motion picture projector, this will include the entire front of the auditorium. The observation port should permit the projectionist to have full view of this area from normal operating position besides the projector in question. Satisfying these requirements is also a simple matter, but calls for careful checking of all dimensions. In some cases it will be necessary to cut the ports with their walls flaring outwards if the projection room walls be excessively thick.

The fundamental requirement of port shutters is that they surely, quickly and quietly close all ports within a few seconds of the inception of any film fire. We respectfully recommend the system of shutter suspension and semi-automatic control adopted by the state of Pennsylvania, or that employed by the Chicago division of Publix Theatres, Inc.

VENTILATION.—Projection room ventilation has two separate and distinct functions. First it must exhaust all of the hot gases from the arcs, remove foul air from the room, and maintain comfortable temperature at all seasons of the year. Second it must be capable of exhausting all fumes from burning film, in the event of a film fire, as fast as they are formed.

The first requirement is best met by two independent systems, one for the room in general, and the other directly connected to the lamp houses. In the cases of the spot-lamps, stereopticon and effect projectors this direct connection may not be practical, but for the motion picture projectors and the flood-lights it is absolutely necessary. The room ventilation system should be capable of making a complete change of air in three minutes. The lamphouse ventilation system should be capable of keeping the temperature of the air in the vent pipe eight inches above the top of the lamphouse at not more than 350° F.

It is very doubtful if, for taking care of the fumes from a film fire, it would be unreasonable to recommend a system having a capacity of 5,000 cubic feet per minute. It should be capable of maintaing the barometric pressure in the projection room during the fire substantially below that of the auditorium so that none of the inevitable crevices will exude any traces of smoke or flame.

Your committee realizes that this section of the report is far from complete, and intends to go more thoroughly into the matter of ventilation in the time between now and the next meeting of the Society, treating the matter somewhat in the manner of stack loss problems in power plant engineering.

Now, after all bare physical fundamental requirements have been taken care of, there still remains a vitally important one which is often overlooked, though it is just as fundamental as those of a more definite nature. The audience sees the picture and other projected effects seated amid the most finished and luxurious surroundings that architects and artists can create. Now if the projectionist views the same picture and effects framed by a dirty, oil spattered unplastered wall festooned with a serpentine maze of conduit, etcetera, can his mental attitude be the same, can his standards of judgment be as high as those of the audience, no matter how conscientious he may be? **Never!!** This psychological stimulus of fine surroundings is a truly mighty force. It is ample justification for the best finished projection suites that any architect can conceive. The man who is not susceptive and responsive to these things has no place in the modern projection room.

This book won't be of maximum use to you if you merely glance through it and lay it on a handy shelf. The man who will benefit most is the man who studies it.

Important New Application in the Projection of Sound and Pictures

THE Projection Department of Loew's Incorporated, of which Lester B. Isaac is supervisor, and M. D. O'Brien assistant, has developed and at the time of going to press with this book, has in operation three installations and what is, I believe, a very important and new idea in the projection of sound and synchronization of motion pictures.

I have examined the preliminary apparatus now in use and have listened to the sound effects. There is no question but what the methods involved are entirely practical. The projectionist in charge of the installation pronounced the thing to be not only very much better in so far as concerns results both in picture and sound, but also more easy and convenient to handle.

I am not showing you illustrations of the apparatus in this book because of the fact that the apparatus now installed, while it works perfectly, is only temporary, and, in so far as concerns convenience, rather awkward.

It is a well-known recognized fact that the necessity for the development of both the sound track and the pictures, where they are both taken on one negative, does not permit of the best possible results to both. If development be carried on solely with regard to best results of the sound track, then the picture development will suffer, or vice versa. It is also a fact that even where the sound of the picture is recorded on separate film and those films are joined in the printing, the effect is not altogether perfect. Without going into details as to why that is true, here is what Loew's Projection Department has done: They have disconnected the sound reproduction apparatus from the motion picture projector and have mounted it on a separate pedestal. This, as I have said, is only a temporary arrangement. Apparatus is now being developed which will join the sound apparatus with the motion picture projector mechanism, but with a vibration absorbing padding between the two. The motion picture part of the film then is developed in accordance with the needs of each individual scene, and at its full width.

Then the sound track is developed on an entirely separate film which carries nothing but the sound track, thus enabling the development of the sound track to its highest possible point of efficiency. This has more than one point of excellence to recommend it. In the first place, as has been noted, it permits of perfection in the development of both the picture and the sound track. In the second place it eliminates the necessity for the use of a screen mask or special aperture plate, because the picture is then of full silent picture size.

The result of this is (and I have listened with much delight to the resultant sound) a smoothness of the sound reproduction and an absolute life-like naturalness. I have not heretofore heard from any other sound reproduction apparatus.

Another advantage in this new plan is that the sound, being recorded on a separate film, can be used a very great number of times more than can a disc recording.

Another very great advantage is that where the film carries both the sound and the picture, the sound track must pass through the intense heat at the projector aperture and, since the heat tends to buckle and warp the film, it follows that the sound track is affected to its considerable injury.

So far as I can determine, the only added labor involved in the projection under this plan is that two films must be cared for and threaded in, rewound, etcetera, but that is, after all, a minor matter, and the fact remains that men who are now handling the apparatus even in this present unperfected form have declared in its favor.

I wish to extend congratulations to Mr. Lester B. Isaac and his capable staff of assistants who have helped in working this plan out. There seems to be no question but what it is destined to be adopted very generally in the near future.

Upon a thorough knowledge of projection and its intelligent application rests picture success, theatre success, and your success.

The Super Simplex

THE Super Simplex comprises an almost completely altered mechanism, and a new stand so designed that the disc record turntable will be located directly beneath the lamphouse. It has several improvements vitally necessary to the handling of sound productions as they are now recorded. The assembly as a whole is shown in Fig. 443. The stand is very rigid and neat in appearance.

LUBRICATION.—Examine and study General Instruction No. 1, page 626, Volume 2. Don't just glance at it. Read and study it.

The oiling system of the Super mechanism is both simple and efficient. Oil tubes extend from A, Fig. 444, to all bearings having their seat in the frame of the mechanism, except one located at C, Fig. 444. This, however, is one of shutter shaft bearings and must not be neglected if you wish to avoid trouble.

AMOUNT OF OIL.—Each of these tubes contains a wick so that the tube may be filled with oil to its top, which will slowly drain down to the bearing as needed. You may therefore fill the tubes to their top, being very careful not to overfill them, thus making a greasy mess, since oil will spread itself around if you will permit any to run out the tube tops when oiling.

Each of these tubes must be filled at the beginning of each day's run. If it be a ten or twelve hour run,

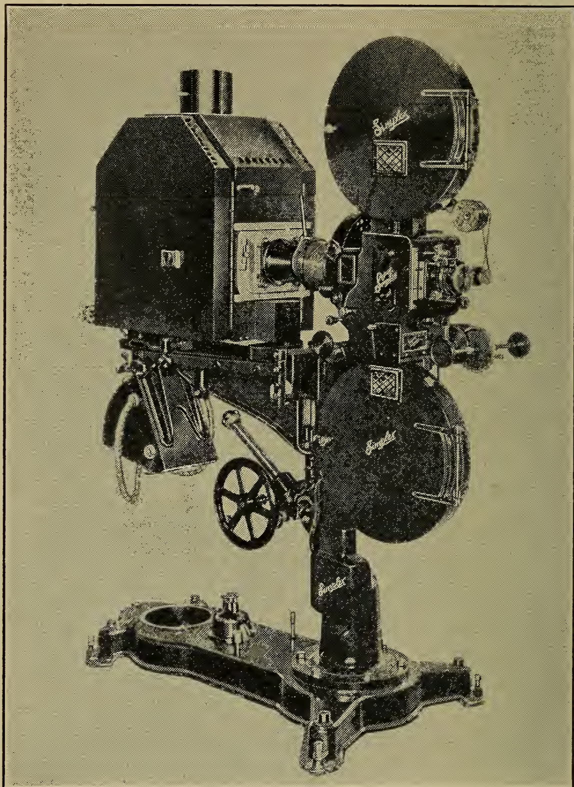


Figure 443.

The Super Simplex.

When projector sets level the height from floor to top of upper magazine is 5 feet 11½ inches. Greatest width on the floor is 2 feet 4 inches at front and 1 foot 8 inches at rear. The new pedestal, known as "Type R Pedestal," may be tilted to an angle of 33 degrees without sound film equipment attached, at which the extreme height to top of lamphouse will be 81 inches. Without sound film attachment it may be tilted to an angle of 38 degrees, at which angle the extreme height is 82 inches.

they should then be again filled before starting the evening show.

NOTE.—Do not overlook either oil hole C, or the tube which is on the top of the mechanism casing, just beside the upper magazine base.

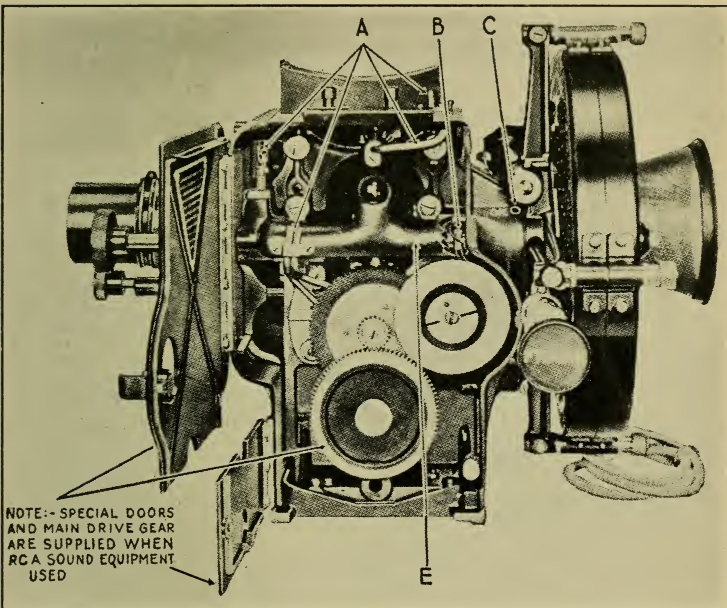


Figure 444.

Non-operating side of mechanism with casing door open. Note fact that casing door is split. Also note framing knob on this side of mechanism. It is a convenience the projectionist will appreciate.

TO FILL THE INTERMITTENT OIL WELL.—The oil tube leading into the intermittent casing oil well is located in the shutter shaft support casing, E, Fig. 444, just above the top of the flywheel. It is marked B in

Fig. 444. This tube leads directly into the oil well. There is no wick in it. The method of filling the well is as follows: First, so set the framing knob that the red line on the oil sight is in a horizontal position. Second, just above the top of the flywheel is a hole in the casting through which a portion of the shutter shaft is visible. The above described oil tube, B, Fig. 444, may be reached only when the red line is set as above directed. **If the projector is set in level position, sufficient oil should be used to bring the oil level up to the red line,** and **no more.** If the projector is set at an angle, as is usually the case, then the projectionist should fill the oil well when the projector is in level position. Then adjust to the projection angle and observe the oil level, which should be thereafter maintained.

Other oil holes serving less important bearings must be made note of while the installation engineer is present, or looked for by the projectionist if no such engineer can be consulted. **These holes should each have one drop of oil each day.** They are as follows: First, the film gate opening shaft has two. Second, one hole serves the rear bearing of the framer shaft. Third, two holes serve the bearings of the shutter adjusting shaft, C, Fig. 445. These two holes are located beneath the framing lamp assembly. Fourth, one oil hole serves the outer bearing of the intermittent sprocket shaft. It is the same as the old type Simplex.

That is all the oil holes but, of course, all parts which slide against each other must have occasional lubricant applied.

GEARING LUBRICATION.—(See page 628, Volume 2.) There is considerable difference of opinion among projectionists regarding the best lubricant for projector gears. However, having considered page 628, Volume 2, remember that Simplex Super gearing is enclosed in a practically dust-tight casing; therefore, a small amount of good, rather heavy oil applied to the

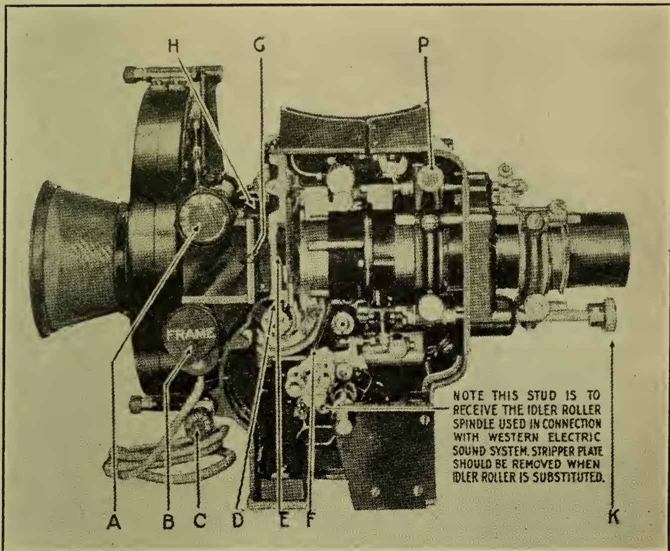


Figure 445.

Operating side with casing door removed. A opens film gate. B is the Framer. C sets rotating shutter within limits. K focuses lens. P is lateral lens adjustment lock.

gear teeth before starting the day's run will serve every purpose of adequate lubrication in this case.

THE ROTATING SHUTTER.—The rotating shutter of the Super Simplex is located between the light source and the projector aperture, and about 5 inches from the aperture. This is a very important change for the reason that fully one-half the total heat from the condenser or mirror is prevented from reaching either the projector mechanism parts or the film itself. This reduction of heat at the aperture is in itself very valuable, because of the fact that of late it, the heat at the aperture of projectors, has been so fierce that not only has film shown a decided tendency to buckle under it, but also the frame of the mechanism has warped under its influence.

Placing the shutter between the light source and the film and mechanism does away with all this, and if it be done rightly it is shown that the results upon the screen are not only equally good, but may actually be better than they were with the shutter in front of the projection lens as heretofore.

In the Super Simplex this reduction in heat is made more effective by slightly angling the shutter blades so that the shutter is itself a mild blowing fan, forcing cold air against the film.

The edges of the shutter blades are deeply vignetted, or made into an exaggerated saw-tooth effect. This, it is claimed, adds something to the effect as the shutter cuts off and again admits light to the film. In Fig. 446 we may examine the shutter construction in detail, the rear perforated casing being removed.

SHUTTER ADJUSTMENT.—The shutter adjustment knob C, Figs. 445 and 449, connects, through a gear train, to the shutter shaft, and by rotating the knob the shutter may be slightly advanced or retarded while the shutter is in motion.

CAUTION.—Before setting the shutter this knob must be adjusted to a point midway of its action, to the end that after you have locked the shutter to its shaft it may be, by means of the knob, either retarded or advanced within the full limits of knob C.

TO SET THE SHUTTER.—The method of setting the shutter is the same as with the old type Simplex. Rotate the flywheel in the direction it normally runs until the intermittent sprocket has rotated a distance of

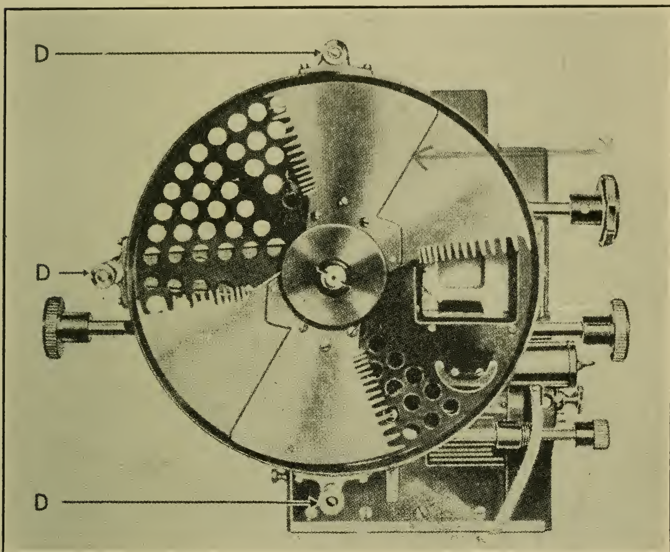


Figure 446.

two teeth or exactly one-half of its total movement, using the lower end of the aperture plate track shoes as a guide. Having set the shutter knob C, Figs. 445 and 449, in its proper position as previously described, loosen the two heavy screws in the flywheel hub which extends out beyond the shutter casing. Move the master blade around (either blade may be used as a master blade for their width is identical) until line X, Fig. 446, is precisely opposite the center of the aperture. Tighten the two hub screws and the job is done.

NOTE.—Before starting to set the shutter, be careful to observe instructions under heading "Shutter Adjustment," page 724, Volume 2.

APERTURE TENSION.—See General Instruction No. 9, page 636, Volume 2, and study it well. Excessive aperture tension is very injurious to both film and projector mechanism.

SILENT AND SOUND APERTURES.—The Super Simplex has two apertures, both in one plate, connected with bakelite handle E, Fig. 445. This handle and the plate with it slides up and down. When at the upper limit of its travel the regular standard 35 mm. film aperture is in correct position. This is for use whenever film on which sound is not recorded is in use. This includes all disc record recording. When the knob is in its lowest position, then the smaller aperture is in place which will accommodate film upon which sound is recorded. However, this aperture is both more narrow and of less depth than is the standard 35 mm. film aperture, the proportional dimensions of both being identical, so that when the smaller aperture is used, the optical axis moved to the right sufficiently to register at the screen center, and the projection lens changed to enlarge the picture to that of the 35 mm. screen image, it will exactly fit the silent picture screen border.

At the time of the compilation of this work, the sound and silent aperture was used as already described, the change being effected by merely raising or lowering the small aperture by means of a bakelite knob extending out on the operating side. This, however, I am advised is to be altered and a system of slip-in masks substituted for the reason that many projectionists and exhibitors demand more than two apertures. For example, three apertures are necessary when Magnascope is added to

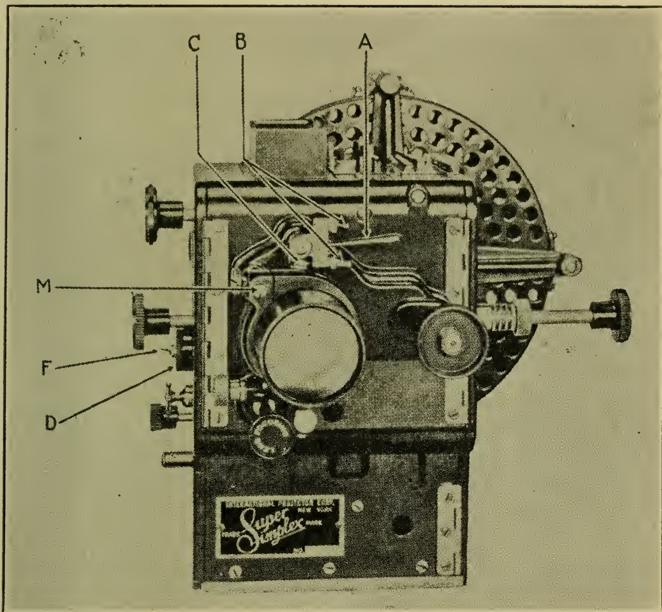


Figure 447.

the sound-on-the-film and silent. Also, effect masks are occasionally in demand. This, however, will not affect the above more than to change from an up and down aperture movement to a slip-in which can accommodate any number of masks.

ALTERING THE OPTIC AXIS OF PROJECTION. Examining Fig. 447, we see a small lever marked A.

This lever may be swung upwards and over in a half circle, and in doing so we move the projection lens just enough sidewise to cause the optic axis of the 35 mm. film projection and the optic axis of the sound film projection to register at the same place upon the screen, and to also in each case have the optical center of the lens opposite each aperture, so that the optical condition is in both cases 100 per cent perfect.

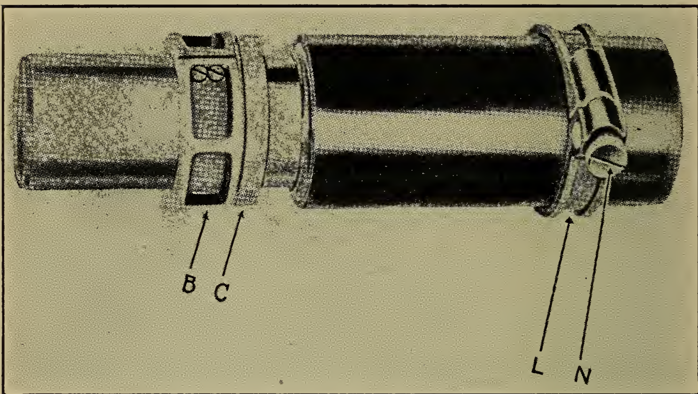


Figure 448.

CHANGING PROJECTION LENSES.—The Super Simplex has been very carefully designed to take care of changing from what we will term silent to sound film. As has been explained, we may alter the aperture and the projection lens center in as little as half a second of time, and the switch can be nothing but perfect. However, in addition to this we must also change projection lenses, and that apparently rather difficult feat has been provided for remarkably well.

In Fig. 448 is seen one make and type of projection lens, together with the adapter ring (left) which fits on it and is clamped to the smaller diameter of the lens. The outer diameter of this part fits into the projection lens frame support G, Fig. 449, which is of course the one nearest the aperture.

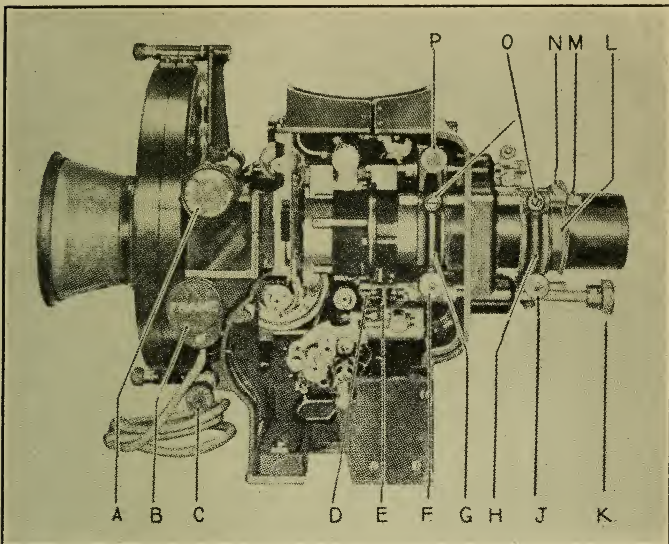


Figure 449.

The center of the three lower parts D, Fig. 450, is a thin shim which slips over the large diameter of the particular lens shown. Some of these lenses are not up to standard dimensions and this shim is necessary in order to bring the larger diameter of the lens up to standard so that it may fit into the front lens supporting casting H, Fig. 449.

The part to the right, F, Fig. 450, is a ring which also slips on the larger diameter of the lens and after the picture has been focused as sharply as possible on the screen, this ring is shoved up snugly against supporting ring H, Fig. 449, and is then clamped tightly to the lens barrel by means of the knurled thumbscrew shown. Hole G of this part receives round rod M, Figs. 447 and 449.

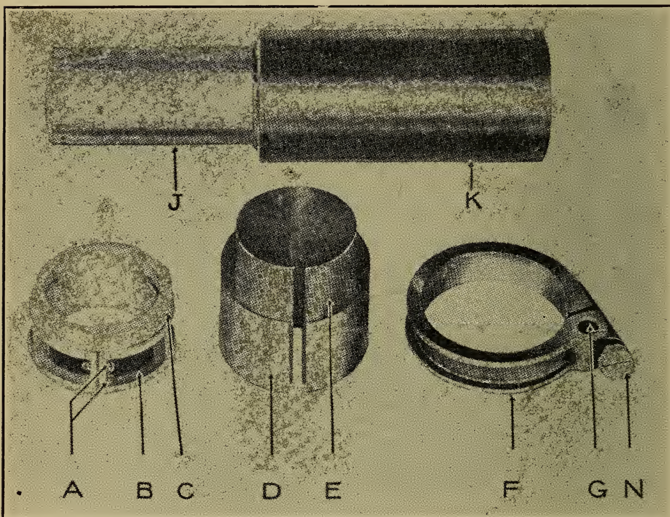


Figure 450.

The operation is fairly obvious. Assuming that the lens required to project silent pictures is in place, the picture is finished and the next one is to be a sound-on-the-film production.

The projectionist moves knob E, Fig. 445, down, thus adjusting the aperture plate for sound-on-the-film. Next he moves lever A, Fig. 447, over to the left, which centers the optical axis on the screen. Thumbscrew P, Figs. 445 and 449, is for the purpose of locking this lever rigidly into place. It may or may not be found necessary to use this lock. It also supplies a slight tension which eliminates possible vibration in the lens centering unit.

FRAMING LAMP.—Just below the eye shield assemblage a small lamp has been provided. This lamp directs a beam of light up behind the eye shield to the projector aperture. A switch is provided. With this lamp lighted the projectionist is enabled to thread in frame. The lamp is a 110-volt, 10-watt one.

To replace this lamp the projectionist must loosen the screw which holds the switch assembly and lamp socket in the barrel, pull the whole assembly out, install the new lamp and replace.

FRAMING KNOB.—When the lettering on the knob is exactly in horizontal (level) position, the framing device is midway between up and down.

INTERMITTENT MOVEMENT.—The design of the intermittent movement remains unchanged with the single exception that the "star" is subjected to a hardening process designed to reduce the wear. After hardening, the star is, of course, ground to a very high degree of accuracy, the tolerance being only one ten-thousandth of an inch. The method of removing the intermittent movement as a whole, which includes the intermittent sprocket and its shaft and the cam and its shaft, remains unchanged (see p. 708, vol. 2) with the single exception that in pulling out the intermittent movement you must be careful to set the framing handle so that the oil tube B, Fig. 44, will have its end located just above the fiber gear at the left of the flywheel. Don't try to pull the intermittent movement out until this oil tube is in proper position or you will probably ruin the tube. Aside from this you have only to follow the instruction above noted in order to take the intermittent movement out of the mechanism.

ADJUSTING INTERMITTENT MOVEMENT.— The intermittent movement should be so adjusted that whereas there will be no binding whatsoever between the star and cam, still when the movement is fully on the lock no rotational movement can be felt in the intermittent sprocket. In other words, the movement must be adjusted as tight as it is possible to adjust it without setting up binding or undue friction between the star and cam.

To accomplish this adjustment it is best to remove the intermittent movement in its entirety from the mechanism. To do this proceed as follows: First, open the door on the non-operating side including its lower part. If the attachment of sound equipment prevents the opening of this door, it will be necessary to remove it by taking out the three screws which hold it on. Next remove the knurled thumbscrew which holds the large diameter pulley and gear. Pull this gear off its spindle. Next, insert a screw driver through the hole in the casing under the projection lens and loosen the screw holding the set collar on the end shaft holding the formica gear just back of the flywheel. Next, remove the set collar. Next, remove the part which carries the shutter controlling knob (see Fig. 445) by taking out the screws at the top and bottom which hold it to the frame. Then looking in at the face of the oil well, you will see two large flat head screws holding steel lugs or fingers. These lugs or fingers when in operation impinge upon the casting containing the oil well and hold the entire intermittent movement in position. Work your framing knob and you will see just what I mean. Loosen these nuts and slip the steel lugs or fingers inward so that they no longer impinge upon the holding casting.

Having done all this, you may, when oil tube B is in proper position as before noted, by grasping the flywheel knob and the fiber gear to the left of the flywheel and partly behind it, being careful to hold the parts evenly and to pull straight outwards, pull the entire movement out of the mechanism.

ADJUSTMENT.—The adjustment of the intermittent movement must be made very carefully. Remember that you are dealing with parts highly tempered, ground to extreme accuracy and in fact having almost the adjustment of a watch. **Never adjust the intermittent movement when the pin is in the slot.** Turn the flywheel knob until the intermittent sprocket has come entirely to rest and set it as nearly as possible entirely on the lock or, in other words, half way between two movements. Next loosen four flat head screws in the face of the side of the movement next to the sprocket. Then make sure that the two screws holding the aforementioned steel lugs or fingers also are loose. You are now ready to make the adjustment. Looking at the face of the oil well on the intermittent sprocket side, you will observe four flat head screws of medium size and the two screws which hold the aforementioned steel lugs or fingers. Make sure that all these screws are loose so that the lid of the oil well moves freely. Next, holding the oil well so that the red line on the oil gauge is horizontal, you will observe just over the "oil level" the end of a small pin. Holding the oil well in this position the cover is pivoted on this pin and will by its own weight accomplish the necessary adjustment.

Putting it in another form of words, with all the screws loosened you have only to hold the movement in such position that the oil tube protruding behind the flywheel is at the top of the movement and the red line on the oil well in horizontal position, whereupon if the screws have been loosened so that the cover is free to move, the weight of the cover will accomplish the necessary adjustment, so that you have only to hold the movement in the position before mentioned and tighten these screws, whereupon the job is done.

CAUTION.—Having done this, rotate the flywheel to make sure there is no binding.

CAUTION No. 2.—When the screws are loose, there will be some rotational movement in the intermittent sprocket, but this will disappear when the screws are tightened up. You then have only to refill the oil well, replace the movement in the mechanism and that's that.

REASSEMBLING.—To reassemble the movement in the mechanism, proceed as follows: Looking at the outer edge of the flywheel you will find at one point in its circumference an "O" punched in the metal. On the face of the metal of the fibre gear which goes partly behind the flywheel you will find another similar mark. Engage the teeth of the fibre gear with the teeth of the small gear on the flywheel hub in such a way that these two marks come exactly together. Next, to the left of the upper part of the opening which will receive the intermittent movement, you will see a formica gear in the hub of which is a taper pin holding it to its shaft. Rotate the mechanism until the large end of this pin stands straight out towards you. Be sure and get this right. When it is right the head of the pin will be directly over the center of the hole which will receive shaft of the large formica gear.

Having done all this, and done it very carefully and correctly, turn the oil well until the oil tube behind the flywheel is against or almost against the large formica gear. Now insert the shaft of the formica gear in its hole, being very careful to hold the gears in mesh all the time; insert the movement and shove it very carefully into place.

Remember, gentlemen, this is not a blacksmith's job you are doing. It corresponds to a piece of watch work, so be careful. Proceed slowly and don't use any hammers.

Don't try to insert the intermittent movement until you have cleaned the outer surface thoroughly and lubricated it slightly with good oil. The rest of the process is merely a reversal of the disassembling, but be very careful to replace the set collar on the inner end of the fibre gear shaft. If you don't do this, you will find the teeth on the gear will be very quickly ruined. Before tightening up the set collar, shove the gear in as far as it will go and shove the collar as far as it will go. There must be no end play at all in the shaft.

THE FIXED FOCUS LENS CLAMP.—This feature of the Super Simplex is unique. Under conditions as they now exist, this clamp is a decided advance in projection procedure, because of the fact that in a large proportion of our present theatres two or more different size aperture openings are employed, or effect masks are used, either of which makes necessary a means for quickly changing from one projection lens to another of different focal length.

Not only is it often essential that this change be made in a minimum period of time, but also the projectionist must know that the newly installed lens will, without any adjustment, project a perfectly focused picture to the screen.

This is all taken care of by the new fixed focus lens clamp, L, Fig. 448 and Fig. 449, and F, Fig. 450, which is locked rigidly to the lens barrel by means of screw N, Fig. 450.

The lens is first mounted without ring L, and the picture is focused as sharply as possible upon the screen. Ring L is then slipped on over the front end of the lens barrel, and shoved back until it rests snugly against the front lens clamp as at L, Fig. 449, whereupon screw N is set up tightly, which locks the ring to the lens barrel in immovable position.

Having properly locked the ring into place it is obvious that if the lens barrel be then pulled out and reinserted, if it be shoved in as far as ring L, Fig. 449, will permit it to go (until ring L comes into contact with lens clamp H, Fig. 449), it will occupy precisely the same position with regard to distance from the film that it did before it was taken out, hence the picture will be in sharp focus on the screen when it is again used.

This being true, it follows that if we have as many rings as there are lenses to be used, and if a ring be installed on each lens as above set forth, then we may pull any one of them out and install any one of the others, with full confidence that the focus of the picture will be perfect when it is used.

Another feature of this assembly is that, not only will the lens always be exactly the correct distance from the film when inserted, but also it will always be in precisely the same position rotationally. This is provided for very simply. Examining Fig. 450 we see that the ring (F in Fig. 450) we have been talking about has a hole drilled through it at G. Turning to Fig. 449 we see rod M, the front end of which passes through this hole in the ring. This may also be examined in Fig. 447, where the end of the shaft is seen at M.

Considering this matter, you will see that since shaft M must pass through the hole in the lens ring, the lens barrel, to which the ring is clamped, will always, perforce, be in precisely the same rotational position, and since the lens barrel is shoved back until the ring encounters the lens clamp, the lens must be always the same distance from the film, with which double check focus cannot possibly be in any degree interfered with by the removal of one lens and the insertion of another, provided the ring has been properly installed on both lenses, and that the lens barrel be shoved in as far as it can go.

NOTE.—There is considerable repetition in the foregoing, but I thought it well to set the matter forth in more than one way.

I might add that in case shaft F, Fig. 449, does not project far enough to enter the lens ring, you have but to loosen screws O, Fig. 449, and shove the shaft ahead, being certain, however, to retighten screws O.

Having previously set ring L, Fig. 449, correctly, to change lenses you have only to loosen thumbscrews F and J, Fig. 449, which releases the lens barrel from its holding clamp, pull the lens barrel out, insert another, shove it back into proper position, retighten screws F and J and the job is complete.

ORDERING LENSES FOR SUPER SIMPLEX.—In case you order Super Simplex mechanism to replace Simplex of the old type, always give both make and focal length of your lenses. This will enable the inclusion of the right lens adapters in the shipment.

If the installation is for a new theatre, the make of lens, the exact width of the picture and projection distance, must be included with the order, so that lens adapters may be included which will fit the lens to the Super Simplex mounts.

NOTE.—Where lens changes will be necessary during the progress of the show, it is essential to quick work that the front end of the lens barrel be located ten and one-half (10½) inches from the projector aperture. If lenses for the Super are ordered, this will be taken care of, when necessary, by means of an adapter collar attached to the forward end of the lens barrel. If, however, you are to use your old lenses on a Super Simplex, then when ordering the projectors, advise as to both make and focal length of lenses, so that proper adapters may, if necessary, be included in the shipment, and annoyance thus avoided.

When examining the chart and drawings which follow, do not feel discouraged. The thing is not nearly so complicated as it seems at first glance. It will soon seem simple enough if you sit down and really study the drawings and charts.

In Figs. 451 and 452 are listed the various parts required to fit any focal length of any make of lens to the focusing mount.

In Fig. 452 we have an assembly drawing of the Super Simplex lens mount and lens shifting device, whereas Figs. 453 to 466 show lenses of different designs, with the necessary adapters assembled in proper position thereon for use in the Super Simplex lens mount.

Examining Fig. 452 we find that detailed information is supplied covering drawing No. 451 and drawings Nos. 453 to 466.

For example, let us assume that we have a 4-inch E. F. B. & L. Cinephor lens, Series No. 1. Referring to Fig. No. 451 and to the column headed "Assembly Drawing Number," we find that assembly drawing No. 4 (Fig. 454) shows the parts necessary for use with this particular lens. In column No. 5, Fig. 451, headed "Assemblies" we find that assembly R-32 is required.

Turning to drawing No. 4 (Fig. 454) we see what R-32 stands for. We find that R-32 for Cinephor requires E-114-R, which is the tube having the external dimensions of a standard Series 2, or "half size" lens, threaded upon one end. R-32 also includes two S-984-R, which are the clamp screws for B-321-R. B-321-R, the adapter for Series 1 Cinephor lens, all focal lengths, also is necessary, as is S-983-R, which is the clamp screw for R-258-R. In addition to these there is R-258-R, which is the fixed focus clamp L, Fig. 448.

NOTE.—R-258-R is required only in cases where a quick lens change is required.

You will note that the parts above named, taken as a whole, constitute assembly R-32. Hence if R-32 is ordered for a 4-inch E. F. Series 1 Cinephor lens—the one used in the example we have just considered—and the parts be assembled as shown in drawing No. 4 (Fig. 454), the lens will fit into the mount perfectly.

IMPORTANT.—It must be noted that in some instances different makes of lens will require almost exactly the same assembly, but that won't do at all. Exactly the right assembly must be used for each lens. For example, examining drawing No. 4 (Fig. 454), it is apparent that very nearly the same assembly is used for quarter size Ross lenses as is required for Cinephor Series 1. However, the Ross requirement is given assembly No. R-33, the only difference between it and R-32 being that the Ross adapter is B-324-R, the diameter of the Ross lens being not the same as that of the Cinephor Series 1 lenses.

Citing another example, suppose we are using a 6-inch E. F. half size Ross lens. Referring to Fig. 451, and column headed "Assembly Drawing Number," we see that for the Ross Half Size lens, 5¾ to 6½ E. F., drawing No. 16 is the right one, so since our lens is 6-inch E. F. we turn to it (Fig. 466), first having glanced at the column headed "Assemblies" in Fig. 451 and ascertained that assemblies R-35 and R-36 will be required.

In Fig. 466 we find the assembly required for our half size, 6-inch E. F. Ross lens. We find that as supplied by the manufacturer our Ross half size lens will fit neither the front or rear Super Simplex lens clamp. We will need adapter assembly R-35 to cause our lens to fit the rear clamp and an extension tube (E-113-R) with threaded adapter A-188-R, to lengthen the lens barrel so that it may be properly held by the front lens clamp.

NOTE.—Many Ross lenses are under the standard diameter. The one we are now considering happens to be one of these. It therefore will also be necessary to use a shim, S-981-R or S-992-R, or possibly both of them, to bring the extension tube, E-113-R up to standard diameter.

With the parts named at hand, we may now assemble them on our lens, and it will fit the lens mount perfectly.

NOTE.—In Fig. 466 we find the fixed focusing collar, L, Fig. 499, in place, instructions for adjusting which have already been given.

ALL LENSES.—No matter what sort of lens you may have, its requirements may be determined by following the procedure just set forth. First examine Fig. 451 and ascertain the assembly drawing number and the assemblies number. Then turn to the designated drawing and it will tell you the rest.

In this I must thank the International Projection Corporation and its Sales Manager, Mr. Griffin, for permitting me to secure my data on this matter from their own very excellent instruction book.

IMPORTANT.—If the focal length and make of lenses are specified when ordering Simplex Super projectors or mechanisms, the correct adapters will be shipped from the factory with the equipment.

LIST OF ADAPTER PARTS REQUIRED ON ANY GIVEN LENS

MAKE	TYPE	FOCAL LENGTH	ASSEMBLY DRAWING NUMBER	PARTS REQUIRED (ONE OF EACH) ASSEMBLIES		EXTRA PIECE PARTS	
CINEPHOR (BAUSCH & LOMB)	SERIES 0	ALL (2 TO 6)	10	R-32		S-995-R.	
	SERIES 1	ALL (3¼ TO 8)	4	R-32			
	SERIES 2	5 TO 5½	5	R-42			
		5¾ TO 7	6	R-39			
		7¼ TO 7½	7	R-43			
		7¾ TO 8½	8	R-43	R-44		
		9	9	R-44	R-40		
SNAPLITE (KOLLMORGEN OLD STYLE)	¼ SIZE	ALL (3¼ TO 8)	10	R-32		S-982-R.	
	½ SIZE	5	11	R-38	R-47		
		5½ TO 6	6	R-38			
		6½	12	R-35	R-38		
		7 TO 8	12	R-35	R-46		
		8½ TO 9	13	R-35	R-40		
SOLAX (KOLLMORGEN NEW STYLE)	¼ SIZE						
	½ SIZE	4¼ TO 4¾	NO DRWG.	R-40			
		5 TO 6	6	R-37			
		6½	14	R-37	R-34		
		7	7	R-45			
		7½	15	R-34	R-40		
		8	7	R-45			
		8½	NO DRWG.	R-40			
ROSS	¼ SIZE	3 TO 5¼	4	R-33			
	½ SIZE	5⅜ TO 6½	16	R-35	R-36		
		6⅝ TO 9¾	17	R-35	R-40	S-981-R	S-992-R
GUNDLACH	No. 1	ALL	10	R-32		S-982-R	
	No. 2	ALL	NO DRWG.	R-40			

SUPER-SIMPLEX LENS ADAPTERS
INDEX TO ASSEMBLY DRAWINGS
-AND-
LIST OF PARTS REQUIRED

DRAWING No 1

Figure 451.

LIST OF ASSEMBLIES AND THEIR COMPONENT PARTS

Assembly No. & Name	Component Parts
R-32 Bushing Assembly Type 1	B-321-R
	S-984-R (2)
	E-114-R
	S-983-R
	R-258-R
R-33 Bushing Assembly Type 2	B-324-R
	S-984-R (2)
	E-114-R
	S-983-R
	R-258-R
R-34 Bushing Assembly Type 3	B-324-R
	S-984-R (2)
	E-112-R
R-35 Bushing Assembly Type 4	B-324-R
	S-984-R (2)
	G-221-R
R-36 Extension Tube Assem. Type 1	A-188-R
	E-115-R
	S-981-R
	S-983-R
	S-992-R
	R-258-R
R-37 Extension Tube Assem. Type 2	A-187-R
	E-113-R
	S-983-R
	R-258-R
R-38 Extension Tube Assem. Type 3	A-186-R
	E-113-R
	S-983-R
	R-258-R

Assembly No. & Name	Component Parts
R-39 Extension Tube Assem. Type 4	A-185-R
	E-113-R
	S-983-R
	R-258-R
R-40 Lens Locating Ring Assem.	S-983-R
	R-258-R
R-42 Extension Tube Assem. Type 5	A-185-R
	E-114-R
	S-983-R
	R-258-R
R-43 Extension Tube Assem. Type 6	A-185-R
	E-112-R
	S-983-R
	R-258-R
R-44 Ext. Tube Ass. Type 7	A-185-R
	E-112-R
R-45 Extension Tube Assem. Type 8	A-187-R
	E-112-R
	S-983-R
	R-258-R
R-46 Extension Tube Assem. Type 9	A-186-R
	E-112-R
	S-983-R
	R-258-R
R-47 Ext. Tube Ass. Type 10	A-184-R
	E-112-R

LIST OF PIECE PARTS

Part No.	Name	Remarks
A-184-R	Ext. Tube Adapter Type 1	Both Ends Fit Tubes (Also No. 2 Gundlach)
A-185-R	" " " 2	One End Fits Tubes Other End Fits Cinephor
A-186-R	" " " 3	One End Fits Tubes Other End Fits Snaplite
A-187-R	" " " 4	One End Fits Tubes Other End Fits Solax
A-188-R	" " " 5	One End Fits Tubes Other End Fits Ross
B-321-R	Bushing Type 1	$2\frac{25}{32}$ O.D. $2\frac{1}{32}$ I.D. $1\frac{3}{8}$ Long
B-324-R	" " 2	$2\frac{25}{32}$ O.D. 2.118" I.D. $1\frac{3}{8}$ Long
E-112-R	Extension Tube Type 1	$2\frac{25}{32}$ O.D. $1\frac{1}{4}$ Long One End Threaded
E-113-R	" " " 2	$2\frac{25}{32}$ O.D. 3 Long Both Ends Threaded
E-114-R	" " " 3	$2\frac{25}{32}$ O.D. $5\frac{1}{4}$ Long Both Ends Threaded
E-115-R	" " " 4	$2\frac{3}{4}$ O.D. 3 Long (for Ross) Both Ends Threaded
G-221-R	Bushing Thread Guard	Used on Bushing when No Extension Tube
R-258-R	Lens Locating Ring	$2\frac{25}{32}$ I.D. $\frac{3}{4}$ Long
S-981-R	Lens Shim Type 1	$2\frac{25}{32}$ O.D. .005" Thick $1\frac{1}{2}$ Long (for Ross)
S-992-R	" " 2	$2\frac{25}{32}$ O.D. .010" Thick $1\frac{1}{2}$ Long (for Ross)
S-982-R	Bushing Hole Shim Type 1	$2\frac{1}{32}$ O.D. $1\frac{15}{16}$ I.D. $1\frac{3}{8}$ Long
S-995-R	" " " 2	$2\frac{1}{32}$ O.D. $1\frac{11}{16}$ I.D. $1\frac{3}{8}$ Long
S-983-R	Lens Locating Ring Screw	10-32 Knurled Head
S-984-R	Bushing Clamp Screw	10-32 Filister Head

SUPER SIMPLEX LENS ADAPTERS
LIST OF PIECE PARTS AND ASSEMBLIES THAT COMPOSE THE SYSTEM

DRAWING No. 2

Figure 452.

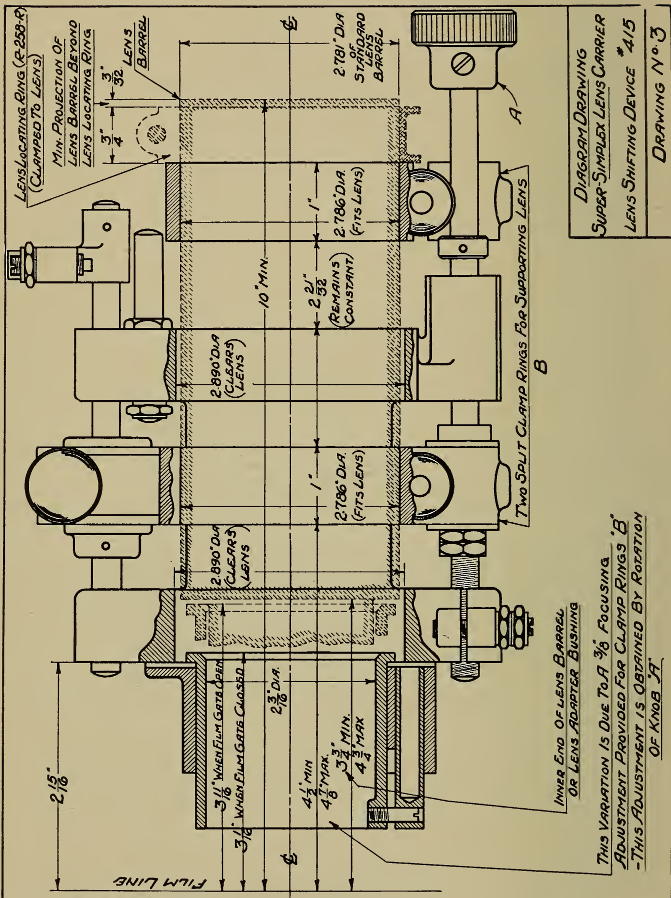

LENS LOCATING RING (R-258-R) (CLAMPED TO LENS)
MIN. PROJECTION OF LENS BARREL BEYOND LENS LOCATING RING
LENS BARREL
2.781" DIA OF STANDARD LENS BARREL
A
10" MIN.
1"
2.786" DIA (FITS LENS)
REMAINS CONSTANT
2.890" DIA (CLEARS LENS)
TWO SPLIT CLAMP RINGS FOR SUPPORTING LENS
B
DIAGRAM DRAWING
SUPER-SIMPLEX LENS CARRIER
LENS SHIFTING DEVICE #415
DRAWING No. 3
WHEN FILM GATE OPEN
WHEN FILM GATE CLOSED
INNER END OF LENS BARREL OR LENS ADAPTER BUSHING
THIS VARIATION IS DUE TO A 3/8" FOCUSING ADJUSTMENT PROVIDED FOR CLAMP RINGS 'B' -THIS ADJUSTMENT IS OBTAINED BY ROTATION OF KNOB 'A'
FILM LINE

Figure 453.

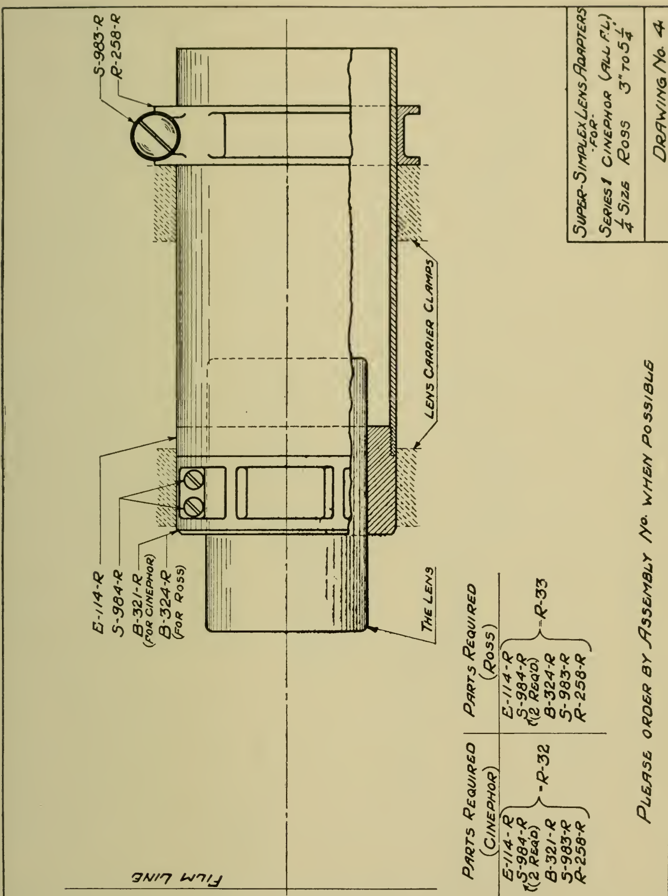

S-983-R
R-258-R
E-114-R
S-984-R
B-321-R (FOR CINEPHOR)
B-324-R (FOR ROSS)
LENS CARRIER CLAMPS
THE LENS
FILM LINE
PARTS REQUIRED (CINEPHOR)
E-114-R
S-984-R (2 REQ'D)
B-321-R
S-983-R
R-258-R
R-32
PARTS REQUIRED (ROSS)
E-114-R
S-984-R (2 REQ'D)
B-324-R
S-983-R
R-258-R
R-33
SUPER-SIMPLEX LENS ADAPTERS FOR
SERIES 1 CINEPHOR (ALL F.L.)
ROSS 3" TO 5 1/4"
1/4 SIZE
DRAWING No. 4
PLEASE ORDER BY ASSEMBLY No. WHEN POSSIBLE

Figure 454.

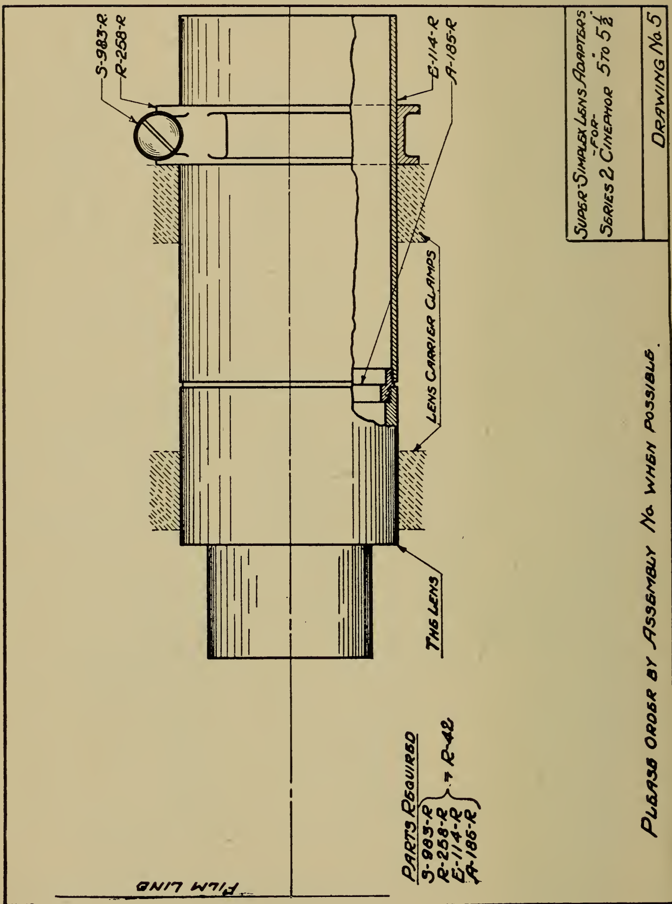

S-983-R
R-258-R
E-114-R
A-185-R
LENS CARRIER CLAMPS
THE LENS
PARTS REQUIRED
S-983-R
R-258-R
E-114-R
A-185-R
= R-42
FILM LINE
SUPER-SIMPLEX LENS ADAPTERS
-FOR-
SERIES 2 CINEPHOR 5" TO 5½"
DRAWING No. 5
PLEASE ORDER BY ASSEMBLY No. WHEN POSSIBLE.

Figure 455.

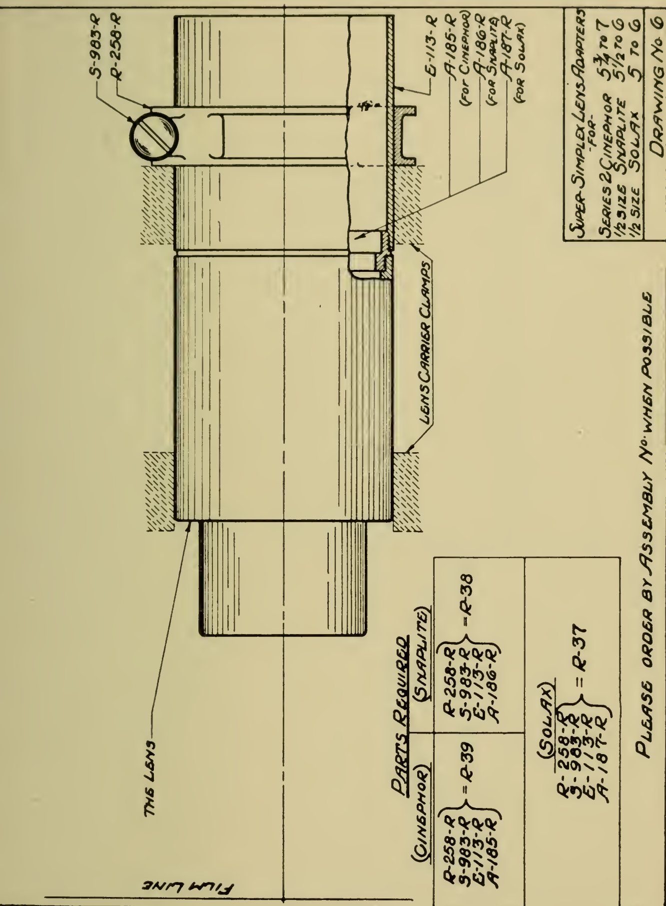

S-983-R
R-258-R
E-113-R
A-185-R
(For Cinephor)
A-186-R
(For Snaplite)
A-187-R
(For Solax)
Super-Simplex Lens Adapters
-For-
Series 2 Cinephor 5¾ to 7
½ Size Snaplite 5½ to 6
½ Size Solax 5 to 6
Drawing No 6
Lens Carrier Clamps
The Lens
Film Line
Parts Required
(Cinephor)
R-258-R
S-983-R
E-113-R
A-185-R
= R-39
(Snaplite)
R-258-R
S-983-R
E-113-R
A-186-R
= R-38
(Solax)
R-258-R
S-983-R
E-113-R
A-187-R
= R-37
Please order by Assembly No. when possible

Figure 456.

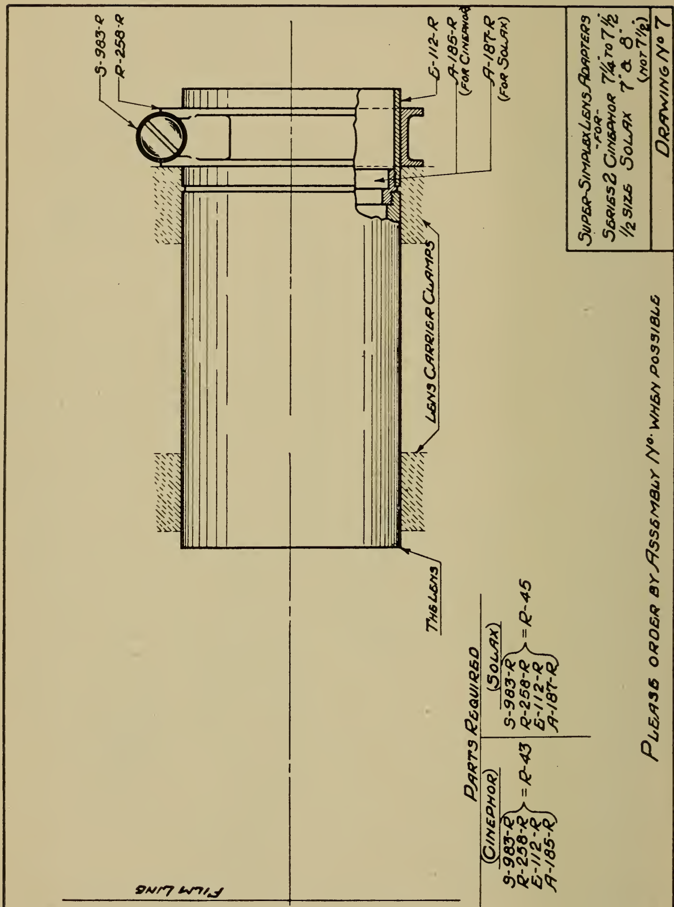

S-983-R
R-258-R
E-112-R
A-185-R (For Cinephor)
A-187-R (For Solax)
Lens Carrier Clamps
The Lens
Film Line
Parts Required
(Cinephor)
S-983-R
R-258-R
E-112-R
A-185-R
= R-43
(Solax)
S-983-R
R-258-R
E-112-R
A-187-R
= R-45
Super-Simplex Lens Adapters
-for-
Series 2 Cinephor 7¼" to 7½"
½ size Solax 7" & 8" (not 7½")
Drawing No 7
Please order by Assembly No. when possible

Figure 457.

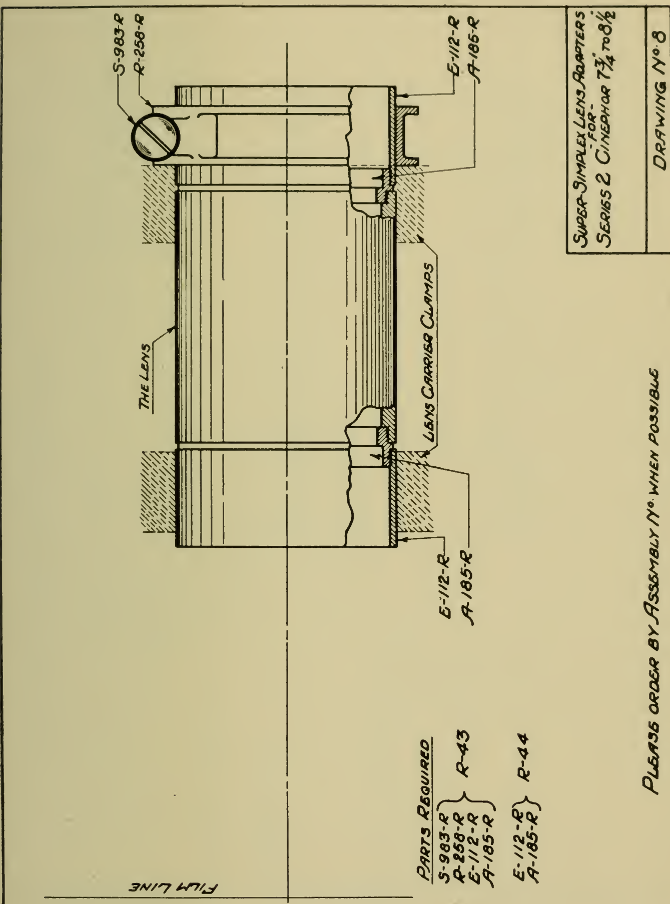
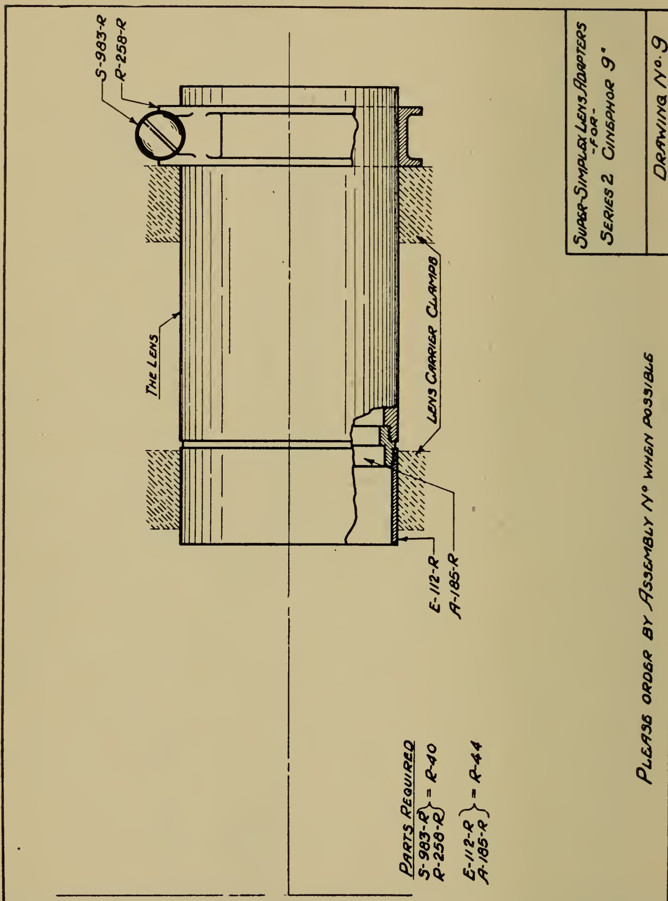

S-983-R
R-258-R
E-112-R
A-185-R
THE LENS
LENS CARRIER CLAMPS
E-112-R
A-185-R
SUPER-SIMPLEX LENS ADAPTERS
-FOR-
SERIES 2 CINEPHOR 7¾ TO 8½
DRAWING No. 8
PLEASE ORDER BY ASSEMBLY No. WHEN POSSIBLE
PARTS REQUIRED
S-983-R
R-258-R
E-112-R
A-185-R
R-43
E-112-R
A-185-R
R-44
FILM LINE

Figure 458.



S-983-R
R-258-R
THE LENS
LENS CARRIER CLAMPS
E-112-R
A-185-R
PARTS REQUIRED
S-983-R
R-258-R = R-40
E-112-R
A-185-R = R-44
PLEASE ORDER BY ASSEMBLY No WHEN POSSIBLE
SUPER-SIMPLEX LENS ADAPTERS
-FOR-
SERIES 2 CINEPHOR 9"
DRAWING No. 9

Figure 459.

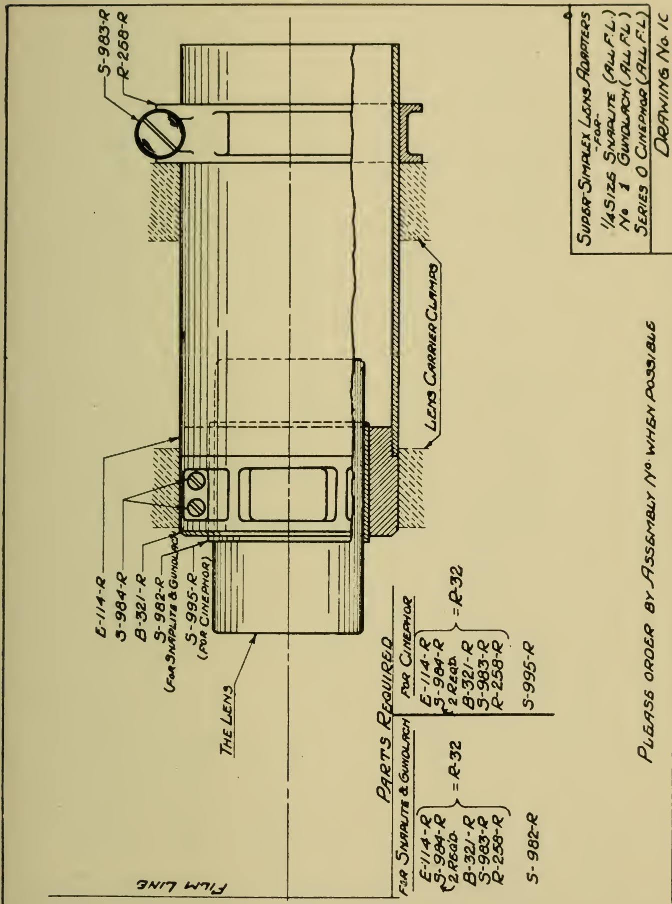
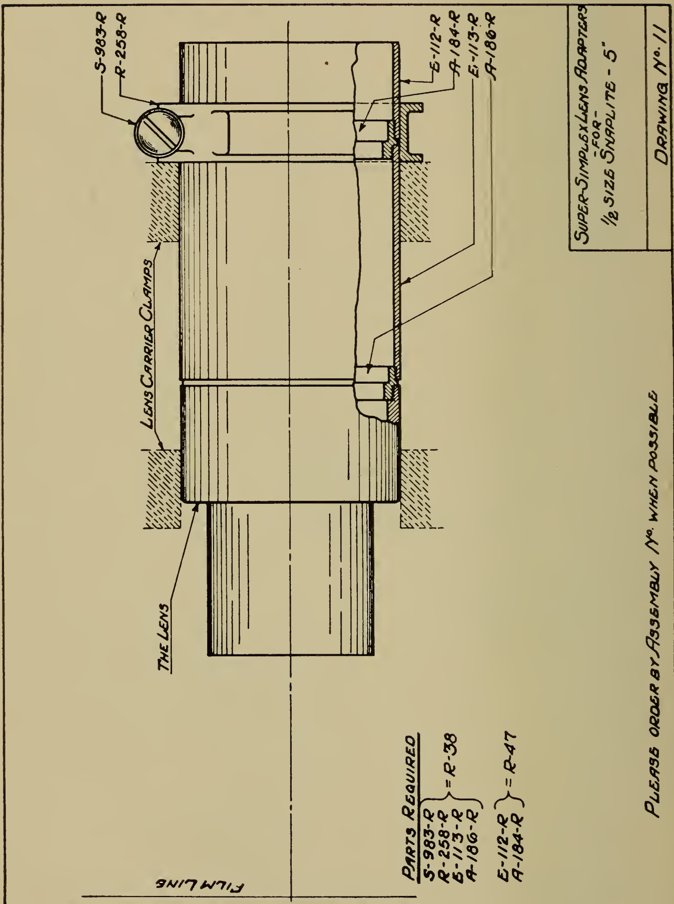

S-983-R
R-258-R
E-114-R
S-984-R
B-321-R
S-982-R (For Snaplite & Gundlach)
S-995-R (For Cinephor)
The Lens
Lens Carrier Clamps
Film Line
Parts Required
For Snaplite & Gundlach
E-114-R
S-984-R 2 Reqd.
B-321-R
S-983-R
R-258-R
= R-32
S-982-R
For Cinephor
E-114-R
S-984-R 2 Reqd.
B-321-R
S-983-R
R-258-R
= R-32
S-995-R
Please order by Assembly No. when possible
Super-Simplex Lens Adapters -for-
1/4 Size Snaplite (All F.L.)
No 1 Gundlach (All F.L.)
Series 0 Cinephor (All F.L.)
Drawing No. 1C

Figure 460.



S-983-R
R-258-R
E-112-R
A-184-R
E-113-R
A-186-R
LENS CARRIER CLAMPS
THE LENS
FILM LINE
PARTS REQUIRED
S-983-R
R-258-R
E-113-R
A-186-R
= R-38
E-112-R
A-184-R
= R-47
SUPER-SIMPLEX LENS ADAPTERS
-FOR-
1/2 SIZE SNAPLITE - 5"
DRAWING No. 11
PLEASE ORDER BY ASSEMBLY No. WHEN POSSIBLE

Figure 461.

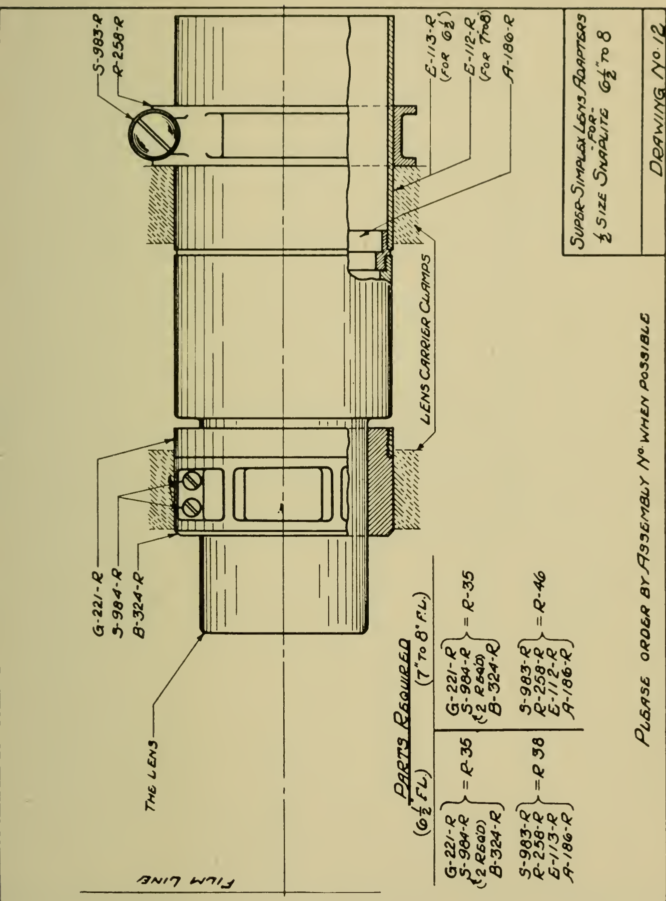

S-983-R
R-258-R
E-113-R (FOR 6½")
E-112-R (FOR 7 TO 8)
A-186-R
LENS CARRIER CLAMPS
G-221-R
S-984-R
B-324-R
THE LENS
FILM LINE
PARTS REQUIRED
(6½" F.L.)
G-221-R
S-984-R (2 REQ'D)
B-324-R
= R-35
S-983-R
R-258-R
E-113-R
A-186-R
= R 38
(7" TO 8" F.L.)
G-221-R
S-984-R (2 REQ'D)
B-324-R
= R-35
S-983-R
R-258-R
E-112-R
A-186-R
= R-46
SUPER-SIMPLEX LENS ADAPTERS -FOR- ½ SIZE SNAPLITE 6½" TO 8
DRAWING NO. 12
PLEASE ORDER BY ASSEMBLY NO. WHEN POSSIBLE

Figure 462.

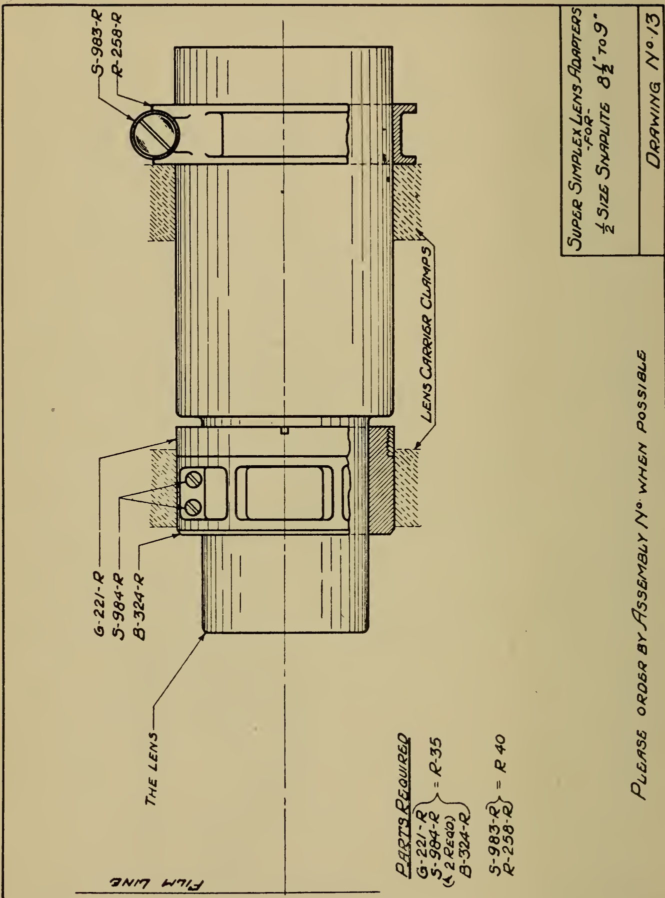

S-983-R
R-258-R
LENS CARRIER CLAMPS
G-221-R
S-984-R
B-324-R
THE LENS
PARTS REQUIRED
G-221-R
S-984-R (2 REQ'D)
B-324-R = R-35
S-983-R
R-258-R = R 40
FILM LINE
SUPER SIMPLEX LENS ADAPTERS -FOR- ½ SIZE SNAPLITE 8½" TO 9"
DRAWING NO. 13
PLEASE ORDER BY ASSEMBLY NO. WHEN POSSIBLE

Figure 463.

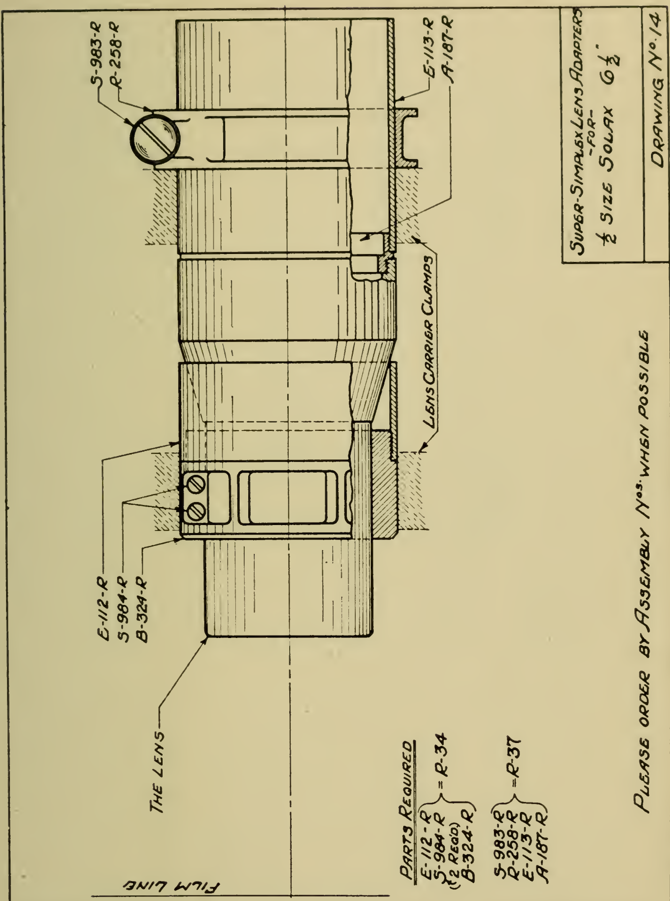

S-983-R
R-258-R
E-113-R
A-187-R
LENS CARRIER CLAMPS
E-112-R
S-984-R
B-324-R
THE LENS
FILM LINE
PARTS REQUIRED
E-112-R
S-984-R
(2 REQ'D)
B-324-R
= R-34
S-983-R
R-258-R
E-113-R
A-187-R
= R-37
SUPER-SIMPLEX LENS ADAPTERS
-FOR-
½ SIZE SOLAX 6½"
DRAWING No. 14
PLEASE ORDER BY ASSEMBLY Nos. WHEN POSSIBLE

Figure 464.

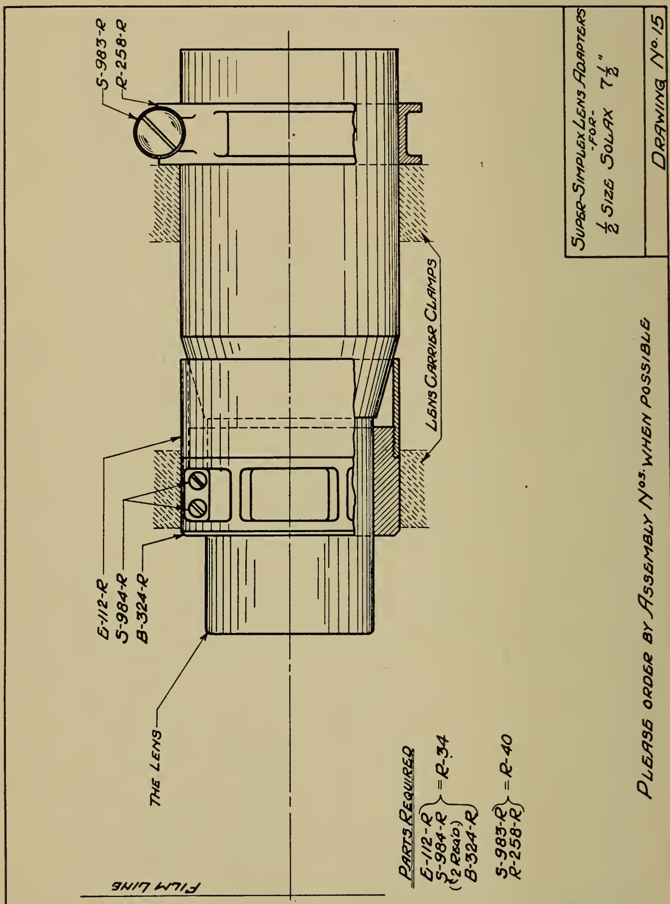

S-983-R
R-258-R
E-112-R
S-984-R
B-324-R
THE LENS
LENS CARRIER CLAMPS
FILM LINE
PARTS REQUIRED
E-112-R
S-984-R (2 REQ'D.)
B-324-R
= R-34
S-983-R
R-258-R
= R-40
PLEASE ORDER BY ASSEMBLY NOS. WHEN POSSIBLE
SUPER-SIMPLEX LENS ADAPTERS
-FOR-
½ SIZE SOLAX 7½"
DRAWING NO. 15

Figure 465.

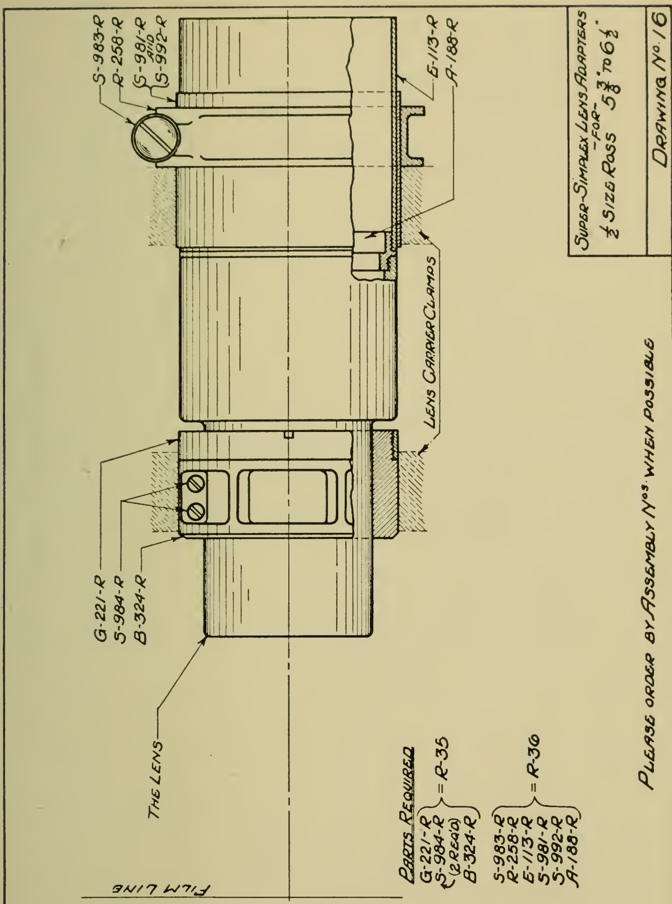

S-983-R
R-258-R
S-981-R AND S-992-R
E-113-R
A-188-R
LENS CARRIER CLAMPS
G-221-R
S-984-R
B-324-R
THE LENS
FILM LINE
PARTS REQUIRED
G-221-R
S-984-R (2 REQ'D)
B-324-R
= R-35
S-983-R
R-258-R
E-113-R
S-981-R
S-992-R
A-188-R
= R-36
PLEASE ORDER BY ASSEMBLY NOS. WHEN POSSIBLE
SUPER-SIMPLEX LENS ADAPTERS
-FOR-
1/2 SIZE ROSS 5 3/8" TO 6 1/2"
DRAWING NO. 16

Figure 466.

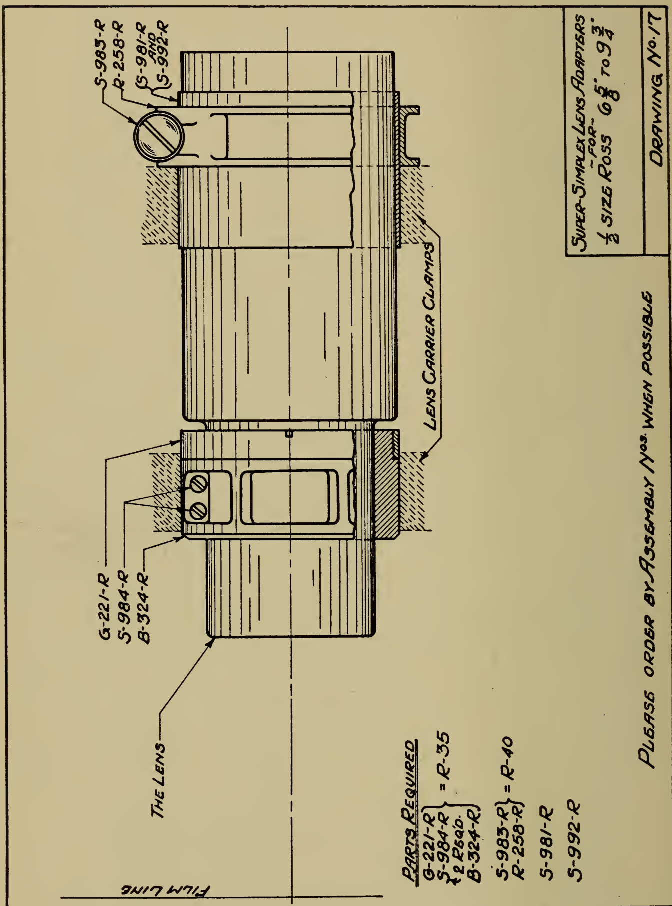

S-983-R
R-258-R
S-981-R AND S-992-R
LENS CARRIER CLAMPS
G-221-R
S-984-R
B-324-R
THE LENS
FILM LINE
PARTS REQUIRED
G-221-R
S-984-R (2 REQ'D.)
B-324-R
= R-35
S-983-R
R-258-R
= R-40
S-981-R
S-992-R
PLEASE ORDER BY ASSEMBLY Nos. WHEN POSSIBLE
SUPER-SIMPLEX LENS ADAPTERS -FOR- ½ SIZE ROSS 6⅝" TO 9¾"
DRAWING No. 17

Figure 466-A.

New RCA Equipment

SINCE this volume entered its first printing some months ago, the RCA Photophone Corporation has reorganized in so far as has to do with synchronized sound equipment, and has put out certain new apparatus deserving of space.

I shall not undertake to give directions for handling the equipment, except as to general principles which are already taken care of in this work and the making of tests, but will give you an understanding of what the equipment is, with the notation—an exceedingly important one, by the way—that it is made by one of the largest corporations in all the world, hence one amply able to guarantee its product and make its guarantee good.

RCA Photophone equipment is now manufactured in five different types, each type designed to meet the requirements of theatres classed according to their seating capacity. The types are known as Type G, Type F, Type D, Type C, and Type B (SPU).

Type G equipment is designed for use in theatres having a seating capacity up to 500. Type F is for theatres seating up to 700. Type D is for theatres seating up to 800. Type C is for theatres seating from 800 to 2,500 and Type B (SPU) is for use in theatres seating in excess of 2,500 persons.

Type G equipment consists of an amplifier having three stages of voltage amplification and one stage of power amplification. A motor generator supplies its power. This equipment includes two RCA Photophone sound heads, one horn, one monitor speaker and two synchronous turntables for sound records.

Type F equipment consists of one amplifier rack containing three stages of voltage amplification and one power amplifier, with the following added items: Two sound heads, one loud speaker, one monitor speaker, storage batteries for filament current supply, one battery charger, a signal system, and two turntables for sound records.

Type D equipment consists of an amplifier rack containing one single channel amplifier, consisting of three stages of voltage amplification and one power amplifier, two sound heads, one input control panel, one-stage loud speaker, one monitor speaker, storage batteries for filament current supply, one battery charger, one signal system and two synchronous turntables.

Type C equipment consists of an amplifier rack containing a double channel, three-stage voltage amplifier and two power amplifiers, which under normal conditions are both used, but which may be used separately in case of an emergency. With this equipment the company supplies the following: two sound heads, one input control panel, two loud speakers, one monitor speaker, storage batteries for filament current supply, a battery charger, a signal system and two synchronous turntables.

Type B (SPU) equipment is the most powerful now supplied. It consists of an amplifier composed of two racks, in one of which is mounted the voltage amplifier equipment consisting of two voltage amplifiers. The equipment is double channeled, which permits of using either amplifier in case of emergency. These voltage amplifiers are three-stage units.

The power amplifier rack contains four power amplifiers, each amplifier supplying one loud speaker. Under normal working conditions all four amplifiers are used, but in emergency any one or more of them may be cut out of the circuit.

With this equipment (Type B, SPU) the following is supplied: Two sound heads, one input control panel, four loud speakers, storage batteries for filament current supply, a battery charger and a visual signal system. As in all types of equipment, synchronous turntables are supplied for each projector.

As has been said, an excellent, comprehensive instruction book is supplied the projectionist with each type of equipment. It is recommended that the projectionist, first of all, study the underlying principles laid down in the Blue Book. Learn how and why an amplifying tube amplifies, for example. Come to an understanding of just how and why a vacuum tube rectifies current, et cetera, through a long list.

By doing this you will put yourself into position to work, with understanding and real intelligence, from the operating instruction book supplied you by the company, which is something you cannot possibly do unless you do understand underlying principles.

Having mastered these things, then study your operating instruction book. Don't merely run for your Blue Book or your operating instruction book when something goes wrong. Study them, to the end that when things do go wrong, as they will even with the best equipment made, you won't have to take time to "look

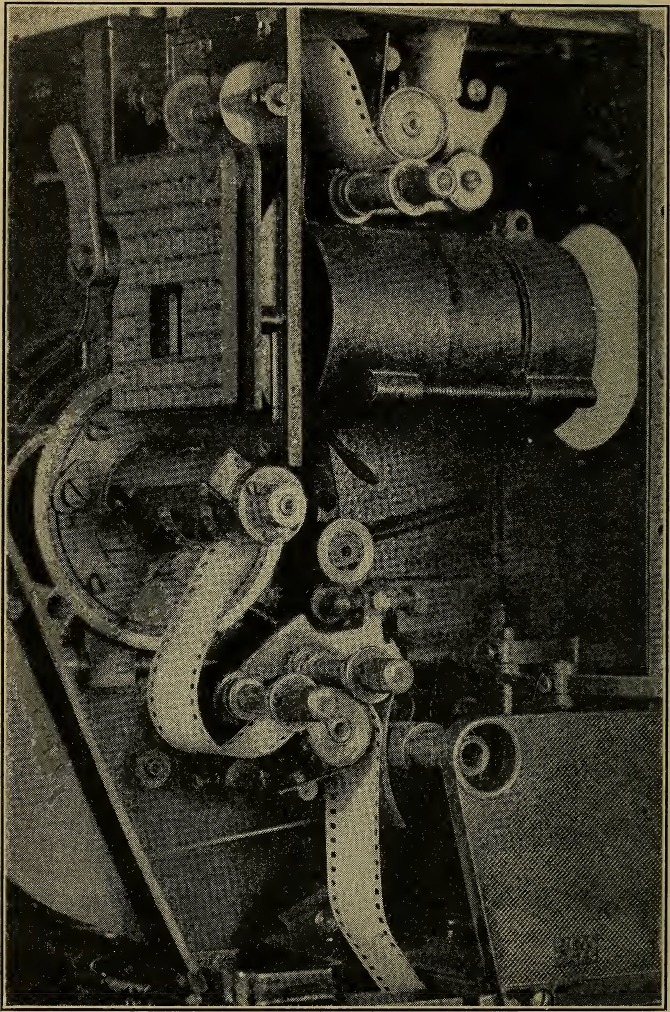


Figure 467.

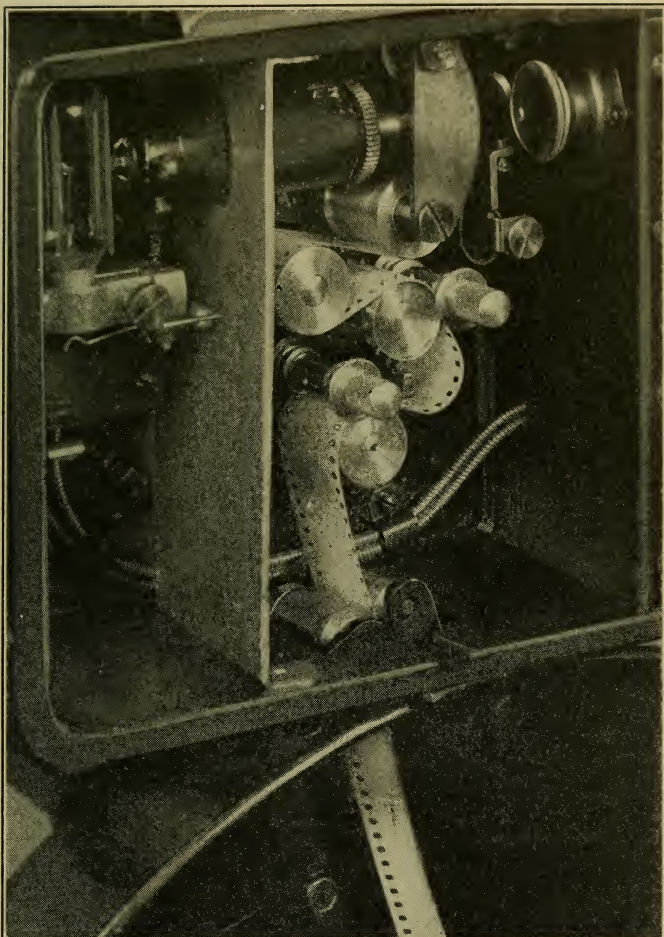


Figure 468.

it up" in the books, because you will of your own knowledge pretty well know what is wrong, and how to remedy it.

We will now show you a series of photographs which will convey an idea of various items of RCA Photophone equipment.

Figs. 467 and 468 show you the working side of a Simplex projector and the sound head, with the projector

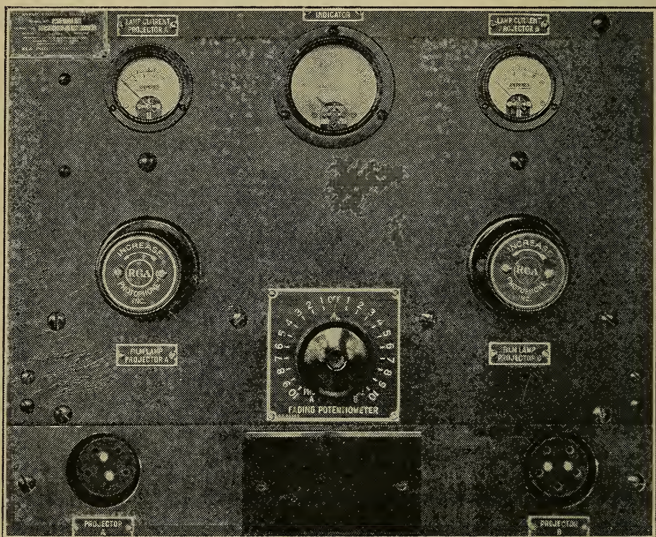


Figure 469.

casing door and the sound head door both removed. Figs. 467 and 468 were one picture. We cut them in two so that the pictures would not be so much reduced in printing. As a matter of fact, Fig. 467 should sit on top of and join Fig. 468.

In the compartment to the left, Fig. 468, is the exciting lamp, so mounted that it may be removed and replaced very quickly in case a filament burns out. These photos are shown you merely to give an idea of the general construction of the apparatus. These two photographs show the path of the film through the mechanism and sound head, with correct loop sizes, et cetera.

In Fig. 469 we have an excellent view of the face of the Input Control panel used with the largest size equipment, Type B (SPU). With this panel the amplifier circuit may be transferred from one projector to the other, which of course is what we designate as "change-over" of sound—fading from one projector to the other.

The controls of this panel are two exciter lamp rheostats, marked "Film Lamp Projector A" and "Film Lamp Projector B."

NOTE.—RCA has adopted the practice of designating one projector as "Projector A" and the other as "Projector B."

These rheostat knobs serve both to switch on the exciting lamp filament current and to control its flow.

Immediately above each of these knobs we see an ammeter, one marked "Lamp Current Projector A," the other "Lamp Current Projector B." These meters measure the current flowing through the exciter lamp of each projector. In operation they must register exactly 7½ amperes.

In the lower center of the panel is the "Fading Potentiometer," by means of which sound is "faded" from one projector to the other at change-over time. You will observe that it has ten divisions on either side. For explanation of Fader action, see Fig. 408, page 1119.

It is not the same instrument type, but the action is nevertheless essentially the same.

The plug receptacles by means of which the sound attachments are connected to the control panel are seen at the lower edge of the panel. A panel slightly dif-

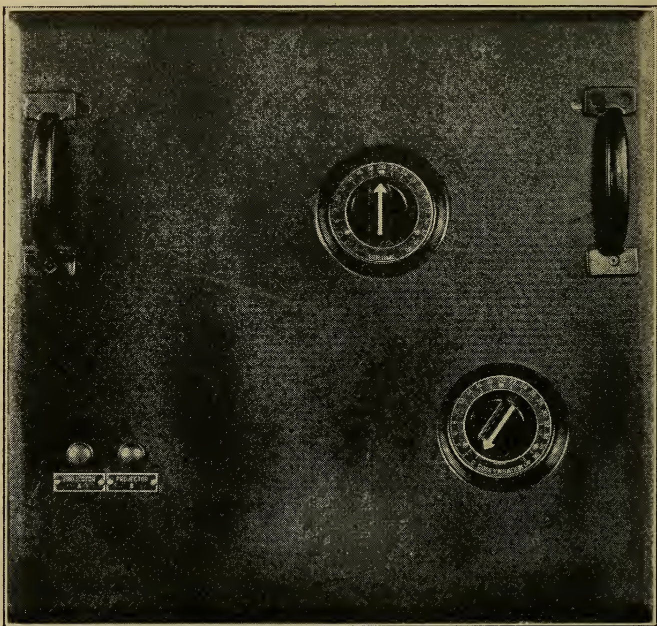


Figure 470.

ferent from this one is used with Type C and Type D equipment. No input control panel is employed with Type G and Type F equipment.

Fig. 470 gives us a view of the Type G amplifier panel, which is quickly removable to permit access to the amplifier. To remove the panel it is only necessary to press the upper end of the two handles shown inward, toward the center of the panel, whereupon it may be withdrawn from the amplifier, a part of the front of which it forms.

WARNING.—Never attempt to remove the panel while the motor generator is in operation.

The upper dial on its face is the one by means of which the volume of the loud speaker is controlled. The lower dial is the "compensator dial," which enables the projectionist to regulate the clarity of sound and secure the best possible results when poor sound recordings must be reproduced and projected.

In the lower left hand corner are two small pilot lamps, indicating which projector the panel is connected to. They are marked "Projector A" and "Projector B." The one burning indicates the projector the connection is made with.

Fig. 471 affords a view of the motor generator set supplied with Type G equipment. At the left is the high voltage (600 volts D. C.) generator which supplies tube plates and photo-cell polarizing voltage for the Type G amplifier. In the center is a generator supplying D. C. at 12 volts to the vacuum tube and exciter lamp filaments, suitable resistances being supplied in the amplifier circuit to properly control the current.

At the right end, as we look at the picture, is the driving motor. It may be supplied either for A. C. or D. C., as per order.

At the top of the rack are the fuses, carried in three blocks. Those to the left are for the output of the high voltage D. C. generator. They are ½-ampere 1,000-volt fuses. The center set of two fuses protect the center

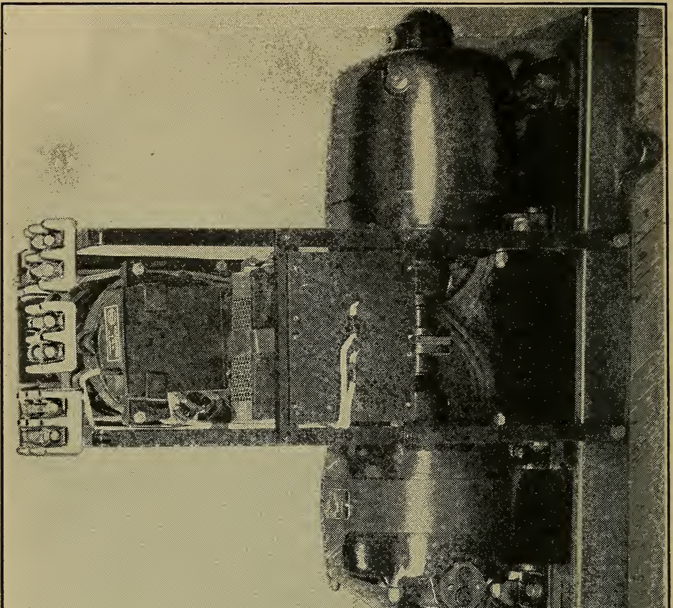


Figure 471.

generator. They are 30-ampere, 250-volt fuses. The block at the right carries two 250-volt, 30-ampere fuses which protect the motor circuit.

DAILY TESTS.—Projectionists handling RCA Photophone equipment must each day perform the following duties and make the following tests.

First—Take a reading of the storage battery electrolyte specific gravity. When fully charged the reading will be between 1.210 and 1.220. A seventy-five (75) point drop in specific gravity is permissible, which means it must not fall below 1.155. Make sure that the electrolyte is high enough to cover the battery separators, adding approved water (see page 1094. In fact, very carefully study all the matter on pages 1083 to 1099, inclusive), if necessary, before starting the day's run. Do not add enough water to cause it to rise higher than just below the filling tubes. See to it that the batteries are clean as to their exterior surfaces, and that the connections are tight and free from corrosion.

Connect one battery to the amplifier circuit.

Second—Clean the projector mechanisms and the mechanisms of the sound heads thoroughly. Oil them, being very careful to use no more oil than is necessary, since excess oil makes a smeary mess and eventually gets on the film, where it does great harm, both to the sound and to the screen image.

Third—Clean and oil the synchronous turntables, making sure that the table disc is perfectly level and that the needle arm is properly balanced.

Fourth—See to it that the grease cup of the synchronous turntable viscous damping device is supplied with grease. Use only white vaseline in this cup. At the beginning of each daily performance this cup should be screwed down one full turn.

Fifth—Clean the sound gates, the exterior surfaces of the condenser lenses of the exciter lamp optical system and the lenses between the sound chamber and the photo-electric cell housing. Never in any way disturb the setting of the exciter lamp optical system. It is a microscopic adjustment. See pages 1142 and 1057.

Sixth—Carefully examine the exciting lamps and make sure they are (a) perfectly clean, (b) that the filaments are perfectly straight and (c) that the light is correctly focused upon the slits. Failure in this will, if fault there be, result in both loss of volume and distortion of the sound.

Seventh—Make sure that your disc record needles are all of the same (a) diameter, (b) length and (c) shape of point. See page 1175.

Eighth—Make sure that the air in the room is as free from dust as possible. Dust in the projection room air does harm in many ways. See page 1104.

Ninth—Make sure that the photo-electric cells are perfectly clean, both as to contacts and exterior surface of glass. Dirty contacts may cause noise in the horns and distortion of sound. Dirty globes will set up volume loss.

When all the foregoing has been carefully attended to, then

Tenth—See to it that the "Special-Projector" switch is on "Projector" and then switch the A. C. power supply to the amplifier.

Eleventh—Snap the voltage amplifier switch to **"on"** position.

Twelfth—Snap the power amplifier switch to **"on"** position.

Thirteenth—Adjust the "Primary Voltage" at 100 volts and keep it there. This is done by means of the "Line Voltage" rheostat.

Fourteenth—Close the exciter lamp switch of projector A by rotating the exciter lamp rheostat for projector A in clockwise direction until the reading is exactly 7½ amperes.

IMPORTANT.—This amperage must be maintained exactly at all times during sound projection.

Fifteenth—Place the "Volume Control" in its normal operating position.

Sixteenth—Set the "Monitor Volume Control" in its normal operating position.

Seventeenth—Check the photo-electric cell as follows:

(a) Place the "Film Disc" switch on "Film."

(b) Transfer the amplifier circuit to the projector under test, if not already in that position, by means of the fader switch.

(c) Open the sound gate and interrupt the light beam by passing an opaque card in front of the exciting lamp optical system lens barrel. A very decided "click" should be heard. If the sound be weak, or if there be none at all, then remove the photo-electric cell and install a new one, whereupon if the new cell be all right the strong click will be heard.

Eighteenth—Check the synchronous turntable projector circuit as follows:

(a) Place the "Film Disc" switch on "Disc" and see that the "Volume Control" is in normal operating position.

(b) Gently rub the needle of the magnetic pick-up with your finger, whereupon a pronounced scratching sound should be heard at the speakers. If no such sound is heard, or if it is weak, then something is wrong and requires attention. Consult your operating instruction book. Do not fail to test both pick-ups.

Nineteenth—In addition to these daily tests, you must at regular, stated intervals, say once a week, carefully examine all electrical connections, making sure they are clean and tight. A loose or dirty connection will set up noise in the horns, as also may dust or dirt on the equipment.

REMEMBER THIS.—If you fail to make complete examinations and tests as before set forth each day, you will certainly not only fail to get perfect results, but sooner or later will encounter serious trouble. The tests and duties we have suggested may seem a lot, but when you have the run of them you will find the whole thing will consume but a few moments, unless of course you should find trouble which requires extra time to remedy.

In Fig. 472 we see the form of photo-electric cell supplied with all RCA Photophone outfits. It is designated as "Photo-Electric Cell UX-868." It has a 4-prong base, the electrical potentials of the tube being connected to only two of them, however. A 90-volt polarizing current is supplied them by the motor generator set.

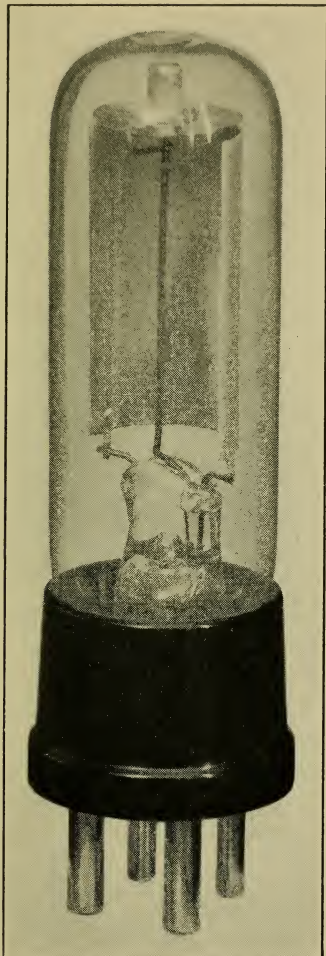


Figure 472.

This cell is exactly the same in its action as the one illustrated in Fig. 387, page 1015, and described in the text on pages 1013 to 1017, inclusive. The only difference as between the two is that in the first one the light sensitive material is on the interior of the bulb, whereas in this one it is carried by the curved metal sheet shown in Fig. 472, also the positive anode is a straight wire instead of ring shape, and instead of excluding light from the bulb or cell by coating its interior surface with silver, it is left clear, but is inclosed in a light-tight casing.

A Practical Slow Rewinder Gearing

AS YOU all should know, the author has recommended slow rewinding for many years. Unnecessary rewinding speed, especially when coupled with reel sides that are not straight, causes much unnecessary damage to films. See page 333, Volume 1. Figure 473 shows the rewinder at the Palace Theatre, Marion, Ohio, made by Messrs. R. S. Slagle and H. J. Seekel, projectionists. The pulley measurements are as follows: Motor speed 1750 r.p.m. Its pulley has two grooves, one ⅞-inch and the other 1¾-inch diameter, all measurements made at bottom of groove.

The idler pulley is attached to a block of iron, which may be made by any blacksmith. It need be only a strip of iron, say ½ inch thick by 2 inches, or even 1½ inches wide. Let it be say 8 inches long, with a right-angled bend 3 inches from one end. The shorter end of the resultant angle should have about three suitable holes drilled in it to receive screws or bolts to fasten the iron down rigidly to the rewinder table. Then, at proper position in the other, now upright end, drill a hole to admit the pulley shaft snugly, with a set screw hole drilled and tapped at one side to hold the shaft in place. The one shown in the photo is attached to the table top apparently by screws put in from below, but that is a detail. It can be done either way.

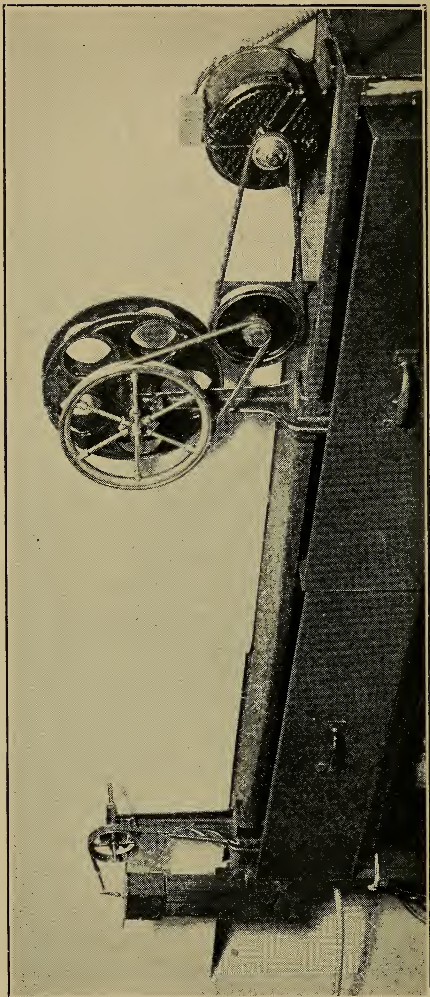


Figure 473.

The idler pulley has two grooves, one 4½ inches in diameter, which receives the motor belt, the other 1¼ inches, which receives the belt to rewinder wheel, as shown. The rewinder wheel is 7¾ inches in diameter. With above motor speed, the rewinding is accomplished at the rate of 60 revolutions per minute if the belt be on the small motor pulley; at 90 revolutions if on the other pulley, which rewinds a 2,000-foot reel in somewhat less than the time required to project a similar footage.

There is, of course, no need for the projectionist to watch the process of rewinding at this slow speed. If inspection is needed, there is a separate, hand-driven rewinder available. An automatic switch, shown in photo, is held closed by the drag of the spring-tensioned belt over the wide-groove wheel on the tailpiece shaft. When the rewinding is completed, the tail reel stops, of course, whereupon the switch drops by gravity. Projectionists Slagle and Seekel report the rewinder as functioning 100 per cent perfect. They have used it a long while. It is recommended that you equip your own rewinder thus.

Thomas A. Edison and Henry Ford were not "lucky." They had brains and used them!

Locating Trouble in Sound Apparatus

NOTE.—For the foundation of and for much of the text of this section we wish to give full credit to the American Projectionist *and to Mr. A. C. Schroeder of the American Projection Society, Los Angeles, California, Chapter. Mr. Schroeder supplied a series of articles already published in the* American Projectionist, *titled "Trouble Shooting," which form the basis of this section. The articles have been very carefully gone over, both by the author of this Handbook and by the ERPI engineers. Mr. Schroeder's procedure in the articles has been adhered to, though some additions and some text changes have been made.*

Mr. Schroeder in the articles in question supplied the first really practical information on hunting for trouble in sound apparatus made generally public and available. In the name of all projectionists we thank him. He very courteously gave permission for our use of them.

IT IS the intention to, using Western Electric equipment as a basis, instruct you, at least in some degree, how to test your apparatus, locate the source of various faults which produce sound troubles, and to remedy the same. It will at this time be impractical to cover this field completely, but we shall at least be able to make a good start.

NO SOUND.—Assuming the equipment to have been put into operation, starting the show, and that there is no sound at all. What should be done?

First of all make sure the exciter lamp is in operation. See that all meters are showing the proper reading. See that all keys and switches are in their correct position.

See that the photo-electric cell is functioning and that the sound gate is closed, though the latter being open should not cut off all sound.

If all this is as it should be, then examine all amplifier tubes to see that they are in operation and that they have the correct filament current.

IN SERIES.—Remember that if a group of two or more amplifier tubes are connected in series, as in the case of certain types of amplifier, then if one filament burns out that will put all the other tubes in the group out of commission until the defective tube is removed and a new one installed in its stead.

If the filament current is low and cannot be brought up to normal, and the tubes operate with current taken from a battery, then you must immediately take a reading of the battery, which will most likely be found to be low. A change to the other battery is the remedy for that, of course, putting the low one on charge immediately.

If, however, the battery is found to be up, then you must look for a ground in the battery filament circuit, remembering, however, that in some hook-ups one side of the filament is grounded for normal operation.

In event no ground, other than the possible normal one, is found, the next step is to take a reading of the plate current of each tube. Should any of them be found to be low, remove the tube and install a tested spare. This completes your test of the amplifier for the no sound fault. If all the things named are found to be O. K., then it is all right and you must seek the source of trouble elsewhere.

LOW VOLUME OR POOR QUALITY OF SOUND.—Should we find the sound to be either too low in volume or of poor quality, or both, first examine the exciting lamp meter and see that the reading is correct as per your equipment instruction book. It must be neither too high or too low, but exactly right. Next, examine the exciting lamp filament. If it is sagged in any degree, discard the lamp and install a new one. See to it that the exciting lamp globe is clean, both inside and out. If the globe is discolored on its interior surface, and it is not a lamp provided with means for removing the discoloration, discard the lamp and install a new one. Test the exciting lamp setting by holding an opaque card, such as the back of an ordinary business card, in front of the sound gate. Upon this card a lighted space will appear, oval in form if the equipment be Western Electric, which if the lamp setting be correct will be evenly illuminated (without shadows) all over its surface. If it is not, then so adjust the lamp (see pages 1057 to 1061) that all shadows disappear and the entire space is evenly illuminated.

When all these things are either found to be right, or have been made right, but the trouble still persists, then proceed to test the amplifier as set forth under **"no sound,"** making certain that all amplifier tubes are functioning properly. Of course, however, it will be understood that poor quality in sound may result from almost any fault any item of the apparatus may develop.

NOTE.—In seeking the source of or cause of low volume or poor quality in sound, or no sound at all, the very first thing to do, if circumstances will permit, is try out the other projector. If sound from it is O. K., we then know the source of trouble lies somewhere in the equipment used exclusively by the one at fault, and may therefore confine our search to it.

If we have done the various things before set forth and have found everything thus far to be all right, we then must proceed to find out in just what other part of the system the trouble lies, remembering, however, that it is not impossible, or even improbable that it may be caused by two or more small faults, each one of which we find and remedy probably will make the others the more easy to locate.

FIRST, IF THERE BE NO SOUND AT ALL, we must test, using head phones, to see just how far the sound is going through the system, in which we may limit our investigation by trying out a disc record. If we get silence from a film but sound from a record (being sure the film used carries sound of normal volume), then we need only to investigate the photo-electric cell batteries, the film disc transfer switch, the photo-electric cell amplifier and the film attenuater.

WARNING.—In testing never use a film carrying low volume sound. It is good practice to secure a strip of film suitable for such tests and keep it ready for use. Don't use a low volume disc or film and then blame the apparatus because the volume is low.

Having examined the exciting lamp, its filament, its setting and the condition of its globe, as before directed, and either found or put them all into perfect condition, connect the head phones across the photo-electric cell amplifier output terminals. If everything is as it should be you will be able to hear the sound, though, of course, not at large volume. The photo-electric cell amplifier terminals location will vary with the system used. Those which do not use the universal base have these terminals, plainly marked on the 6-pole switch on the front wall. If the universal base is used, they will be found within the housing of the amplifier.

WARNING.—No matter what system you may be using, don't wait until trouble shows up to find the location of these output terminals. Have your Service Engineer point it out to you. If there is no Service Engineer, then have the Installation Engineer show you where they are. If you fail to get this bit of information from either, then it is up to you to dig it up for yourself, or else write the manufacturer of the apparatus requesting the desired information.

If, when making the head phone test at the photo-electric cell amplifier, you get no sound, then brush your finger across the lead coming from the photo-electric cell. This refers to Western Electric equipment and the lead attached to the binding post or soldered to the lug on the bakelite strip is meant—**not** the one which is grounded to the case. The finger scraping should produce a sort of scratching or scraping noise.

If you get this noise all right, then remove the sound gate and pass a finger up and down through the light beam close to the gate. Each time the finger is passed through the light there should be a loud click. If there is not, then assuming the exciter lamp and its optical system to be O. K., we may conclude that the trouble lies in the photo-electric cell itself, which should be removed and a tested new one installed.

Of course if our head phone test at the photo-electric cell amplifier produces no sound, then it is fairly certain that the trouble lies in the cell, though we cannot be certain of that. It is always possible there may be a short in the line connecting the photo-electric cell amplifier and the film attenuater, and the photo-electric cell working all right, but all the amplified signal passing through the short and none through the head phones. In this case there would of course be no sound beyond the photo-electric cell amplifier.

Of course should the sound come through at its normal volume for this point up to where our head phones are connected, it is conclusive proof that everything up to and including the photo-electric cell amplifier is in good condition.

THE 41 AMPLIFIER.—Having thus made certain that the sound is O. K. at the photo-electric cell amplifier output, our next test will be at the 41 amplifier input, if it be Western Electric equipment, or at the input of whatever corresponds to it in other equipment.

Should we be unable to get sound here, we must of course get busy and find just where the loss occurs. We now connect our head phone terminals across the film attenuater output terminals. Lack of sound here of course indicates the trouble to be between those terminals and the photo-electric cell amplifier terminals.

WARNING.—Ordinarily we know that trouble lies between the last point at which sound was heard and the point where it is absent. However, there is one possible exception to this, viz.: where a ground or short exists beyond the tested point. This will cause it to appear that the trouble is ahead, whereas it really is not.

In event the sound comes through the film attenuater all right, connect the head phone terminals across the film-disc transfer switch. On most systems the terminal lugs will be found at the back of the board upon which it, the switch, is mounted. However, it might be well to first, with the switch at "open" position, connect across the input terminals. If sound comes all right here, then set the switch on "Film" and test the output terminals. If we get sound here, we may know that the switch and everything between it and the exciting lamp is in good order, or at least not responsible for our no-sound trouble.

Should we find it difficult to either locate or get at the transfer switch output terminals, we may save time by locating and testing from the fader input terminals from the projector we are trying to clear up. If it be Western Electric equipment, the input terminals from each projector will be plainly marked. This also is true of most other equipments. On Western Electric equipment they are at the bottom of the fader. In fact, this test might well be made without bothering with the transfer switch, because it we get sound here we know the switch must be all right. If we don't, we may then go back and test the switch, of course.

We next proceed to connect our head phone terminals to the fader output terminals, which on most equipment are plainly marked. If the sound is all right at this point, then the fader is O. K. as well as everything ahead of it.

NOTE.—When testing, be careful that your phone terminal connections are good. Merely holding them in contact with your fingers will not always do, as at points where the signal will be weak in any event, your fingers, plus a possible none-too-good contact, may serve to kill the signal entirely, thus producing a deceiving result. Better take time to make a thin copper clip which may be easily slipped under a loosened clamping screw, and the screw then tightened down on it. Takes a bit more time, but on the other hand you are sure the result is thoroughly dependable.

As already set forth, should there be no sound at the 41 amplifier input terminals, or whatever corresponds to it in equipment other than Western Electric, we may know the sound has stopped at some point between the photo-electric cell and that point; that is, if we know everything is O. K. up to and including the photo-electric cell. The reason for jumping from the photo-electric cell to the input of the 41 amplifier is that were the trouble in the latter or further on, we would be saved the time spent in testing between the amplifiers, that whole circuit being tested at one operation at the 41 input terminals.

If everything is found to be in good condition up to the 41, then we will jump to the input of the 42 amplifier, if one there be, and then on to the 43, all of which may be very quickly done if no trouble develops at either point. Of course if the 42 input is found clear, but the 43 bad, we then go back and make tests of the circuit and apparatus between those two points.

From the output of the 42 or 43 we proceed to the output panel, on the rear of which (Western Electric equipment) will be found a small bakelite panel, to which several lugs are attached, each marked to indicate the circuit to which they attach.

Before testing further, turn off all horn keys except one on the front of the output panel. Have the control switch for that one set at 0. Then place the head phone terminals across the two lugs connected to that circuit. Test each horn circuit in the same way.

Do not fail to test each horn circuit separately. Should one of them have a short and all the others be clear, still they would all be affected by that one short.

If we have found sound clear up to the output to the horns to be O. K., we then know positively that the trouble will be found either in (a) the horns themselves, which is extremely unlikely since all horns would hardly go "out" at once; (b) in the horn circuits or (c) in the circuits supplying field current to the horns.

First we carefully check the fuses in the field current circuit. They will be found on the battery charging panel. If these are all right, next examine the fuses serving the same circuits on the stage.

Should the stage fuses be blown, or the horns not again plugged in when they have been removed for vaudeville acts or other reasons, then that fact will be shown by sound coming from the monitor horn, but not from the stage horns.

To check the disc part of the apparatus, select a record known to the projectionist to be in good condition and to carry sound of normal volume. Play this record and connect the head phones across the output terminals of the reproducer. If sound is heard, then of course the reproducer is all right. If there is no sound, then we know the reproducer is faulty, **unless** there happens to be a short or ground between the reproducer and fader. Should you suspect this, disconnect the reproducer and test again. If there is sound, that settles it. The reproducer is O. K. If not, then the reproducer certainly is faulty.

From this point we test (a) the line between reproducer and transfer switch for ground; (b) the transfer switch and the fader, testing each piece of apparatus as already set forth, except of course that at the input to the transfer switch, the terminals connecting it to the reproducer will be tested, instead of those leading to the PEC amplifier.

TO REMEDY TROUBLES.—If the directions before set forth have been faithfully followed, we should then know at least approximately where the trouble lies, and therefore are ready to consider what should be done to effect a remedy.

PHOTO-ELECTRIC CELL ROTATED.—If from our tests it appears that the photo-electric cell is not functioning properly, first make sure that its "window" is free from any deposit of grease or dirt. Next make sure that the light beam is all entering the cell window. Due to vibration it sometimes happens that the photo-electric cell will very slowly work around (rotate), so that in course of time its window will be partly out of the light beam. This will of course mean loss of light, and therefore of volume. It may (or may not) also sometimes set up more or less distortion of sound. **The remedy** is obvious. Return the cell to its proper position by rotating its base.

PHOTO-ELECTRIC CELL GROUND WIRE.—A loose ground wire will set up noise. If the wire be broken, then the cell will appear to be dead. First, with the light beam entering the cell, touch it, the cell, gently with your finger. If the action sets up noise, and plenty of it, then you will probably find the screw which holds the ground wire to have worked loose. Remove the screw, clean the wire and screw head and re-make the connection, setting the screw up as tight as you think it will stand, whereupon all should be well.

If the cell appears to be dead, then examine its ground wire and make sure it is not broken, probably close to its connecting screw.

TRY NEW CELL.—If the photo-electric cell is found to be in proper position rotationally, and its ground wire in perfect condition, then try replacing the cell with a new one which has been tested, or with the one from the other projector, which it is assumed is working perfectly. If this stops the trouble, you of course know its seat is in the cell you have removed, and the spare cell is therefore kept in service, the old cell being thrown away.

CAUTION.—All photo-electric cells are carefully tested before being shipped out to theatres. However, things may possibly happen to them in shipment, therefore **every new cell should be tested as soon as it is received,** which may be done by installing the new cell in place of one which is working perfectly. If it also works perfectly, then you may remove it, packing it away carefully for use as a spare.

SPARE CELLS.—Two spare cells should be kept on hand, because of the fact that should one cell go wrong and you must place your only spare into service, you are then left without a spare until another can be secured from the supply dealer, under which condition you are "sunk," should anything go wrong with either the one you have just installed, or with the other cell before the new spare arrives. If, however, you have two spares, then there is not one chance in a thousand that you will be thus caught without a spare, provided, of course, that you order immediately when a cell must be replaced with one of the spares in stock.

PEC FUSES.—Have plenty of PEC battery box fuses always on hand. These fuses are more or less unreliable. One of them may test perfectly today, and tomorrow, without any apparent reason, be either noisy or blown. It is best to test them every day before starting the day's run, as follows: Connect two wires to a small battery, with a small buzzer in the combination. Hold these wire ends in firm contact with either end of a fuse, while you tap the fuse lightly with a screwdriver, wrench or other handy implement. When you place the wire ends in contact with a live fuse, the buzzer will of course sound. Should it stop, even for the smallest fraction of a second when you tap the fuse, discard the fuse and install a new one. Of course if the buzzer does not sound at all, then you may know the fuse is "open," and put in a new one.

NOISY B BATTERIES.—B batteries which have been used too long will set up a sort of "frying" noise. An occasional new B battery will do the same thing, though not at all often. The only remedy is to change the battery. Nothing can be done with the old one. It is useless.

TIGHT CONNECTIONS.—Anything in any degree loose, either in an amplifier or in any circuit connected therewith, will set up noise, and the location of the fault is not always easy to discover.

Should you have reason to suspect noise or other trouble to have its seat in something of this sort, first of all make a very careful examination of the amplifier you suspect. Go over every connection and every circuit with the most minute care. See to it that all connections are clean and tight, and by clean it is meant that not only must the metallic contact be perfect, but also there must be no dust or dirt smeared or settled across the insulation, or any fine wire strands either.

NO OIL.—You must, and if you are a competent projectionist will make sure that no oil or grease is permitted to be or remain on any electrical connection, because while oil is itself an effective insulator, still it collects dust, and dust very often carries minute metallic particles, hence dust laden oil may well form a path for current in small quantities, but **small current leakage may mean large noise production** just the same. Usually this kind of leakage sets up a sort of frying noise. It may also cause **loss of volume,** if the leakage be at the right point. It is even possible that it may render **the entire amplifier action intolerably bad,** if such a condition obtain at a condenser connected between the plate of one tube and the grid of the next one. This is for the reason that, with dust collected in oil across the dielectric of such a condenser, the plate voltage supplied to one tube will leak through, and of course be impressed upon the grid on the other side, which will set up both distortion and amplification loss, because of the fact that the grid is no longer negatively biased. If the leakage be heavy, it may even be positively biased by the plate voltage.

This condition comes on slowly, of course, as the dust gradually collects in the oil. It is without excuse, and will never occur if the projectionist looks after his equipment, making frequent, painstaking, thorough inspections.

THE NEXT STEP.—If you have made this examination and find no fault in the amplifier connections, circuits, et cetera, then **try a new set of tubes.** Occasionally one of the tubes of a set may become microphonic, hence noisy. A microphonic tube which cannot be used in a PEC amplifier, may ordinarily be used in the 41 amplifier. However, a noisy tube used in a 41 still will be noisy, though not in so great a degree, because of the fact that there is much less amplification following it. **We do not recommend using a noisy tube.** It is poor practice to try to "save" a small sum by using a noisy PEC tube in the 41. You have **not removed the noise,** you have merely lowered it somewhat. When you find a tube to be noisy, discard it. If you don't, it will, in all human probability, cost your box office the price of several tubes in lost business.

THE NEXT THING TO DO.—Next, move the tubes around in their sockets to test the prong contacts. Then provide yourself with a bit of dry wood about the diameter and length of a new lead pencil. This is so you may work around the various amplifier connections, et cetera, when the current is on, without danger of setting up a short.

Using this stick, with the current on and the head phones connected across the output of the PEC amplifier, gently pry and push the various wires around. If there are any loose connections, that fact will manifest itself in the phones instantly it, the loose connection, is moved.

BEWARE OF SOLDERED CONNECTIONS.—It is not at all impossible that you may discover trouble in soldered connections which look, to the naked eye, to be in perfect condition. Joints which are soldered without using sufficient heat can never be confidently relied upon. Such a solder job may be recognized by its rough appearance. A well made solder joint will always be smooth and shiny looking.

HOW TO DO IT.—Should you resolder a joint, heat your iron to proper temperature and hold it on the joint until the solder flows freely. It may in fact seem to all flow off, but neverthless sufficient solder will remain in and on the joint to make a good job of it. If your iron is not hot enough, or you fail to heat the joint sufficiently, there will be a big lot of solder on the outside, but the joint will not be well soldered just the same.

WARNING.—Do not use the monitor. Use the head phones for such work as this. Should you use the monitor, and jar a poor contact, the shock may possibly be sufficient to ruin the monitor. **Always set the fader on zero** when engaged in such work.

Assuming you have used your little stick effectively, and thus have tested all the wire connections, et cetera, and have found everything O. K., the next step will be to examine the various amplifier parts themselves.

The first two tubes of the 3-tube amplifier (Western Electric) equipment not using the Universal Base, have their plates connected to the same tap on the batteries—the 45-volt tap.

Break the plate circuit of the second tube and connect the head phones in series with it. In Western Electric equipment the most convenient place to do this is on the left side of the projector, in the small compartment under the sound head where two transformers and a small terminal strip are housed.

Disconnect one of the wires connecting with the primary of the input transformer. They are all marked.

If in doubt, you may consult the diagram on the cover of the amplifier. You will find two coils marked "Input Transformer."

Make note of the one connected to the plate of the tube ahead of the one where you broke the connection. You will find the same numbers on the transformer itself.

Connect the head phones in at this point, and put the amplifier tubes into operation—light them. If you hear the noise here, it is positive evidence that it is somewhere ahead of this point.

NOTE.—When doing this the sound will be very low, hence things must be quiet and you must listen very carefully. If you can hear the noise here very plainly, then it is in fact pretty loud, because at this point sound is at a low level. It is possible the sound may be ahead of this point, even though you are unable to hear it. However this is not at all likely if you listen carefully and the phones are in good condition.

WARNING.—Make sure, first of all, that your head phones are not only good ones, but also that they are in good condition. No use testing with a poor testing tool.

NOTE.—The system we now follow is much the same as was previously used in testing the whole system, except that now we are attempting the more difficult task of ascertaining the particular point at which it is in a particular amplifier, and that is much harder, requiring very careful work.

Assuming we have heard the noise in the test just described, we will now connect our head phones into the plate circuit of the first tube of the amplifier. In

Western Electric equipment this is most easily done on top of the amplifier, where the wires leading to the terminal strips on top are soldered to the lugs. If the noise can be heard here it is located either in the parts, or in the wiring of the first tube, though it may be even ahead of that in the PEC amplifier or in the exciting lamp. It, of course, cannot be in the film, because we are using no film in this test.

In case the noise is found not to originate in the first stage of amplification, but is heard in the plate circuit of the second stage, then it of course has its seat between the two, and as there are not many parts which can be involved, it should be easy to locate. It may, however, be necessary to replace each of those parts, in turn, with other parts known to be good.

TESTING AMPLIFIER PARTS.—It is never safe to assume that any part of an amplifying system is in good order when received. They must be tested and the best way of testing amplifier parts, or in fact the only way available to the projectionist, is to install them on an amplifier which is producing no noise. If the operation is still silent after installation of the part to be tested, then you may know the part is O. K. Of course when we say "no noise," we do not mean sound which the amplifier is supposed to produce, but frying noises, popping sounds, howls, whistles, et cetera.

The parts include: (a) one condenser; (b) one grid leak; (c) one socket; (d) the primary of the input transformer; (e) the wiring; (f) the springs by means of which the amplifier is suspended, which really is in a way a part of the wiring. They carry current from the terminal strip at the top to the one at the bottom.

These various parts must be replaced by others, one after the other, until the noise stops. The tube is not included, because of the fact that we tested it when going over the system as a whole previously. Also we may consider the filament circuit as probably all right, else the noise would have been heard in the first stage.

It also is unlikely that the springs will develop noise. They need only be replaced after everything else has failed. Something rubbing against one of them, or any part of one of them, could cause the noise. **At each end of each current carrying spring** you will find a small, flexible connector soldered. The other end of the "pig-tail" you will find soldered to the lug on the terminal strip. Should the connection at either end of a pigtail become loose, you may expect plenty of noise when the springs move in absorbing vibration.

NOTE.—Head phone terminals should never be held to the part terminal with the hand. If you do that, then the fingers may and probably will absorb enough of the electrical energy to make the sound inaudible. Instead, attach wires to the terminal ends of which you have soldered spring clips. You then may always secure satisfactory, effective contact by merely attaching the clip to the part. Always solder the wire to the clip near where it will clamp the terminal or wire, so as to involve little of the high resistance of the iron or steel.

In addition to the clips it is well to also solder two pieces of about No. 8 wire to the wire near its ends. Wrap them with insulating tape to one-eighth inch of their ends. With these you may reach into otherwise inaccessible places to make a test. These may be normally held up against the wire insulation by means of rubber bands, so that they will be out of the way when using the clips. Don't neglect to wrap them well with insulating tape to prevent causing a short when using them.

If any part is producing noise, and you connect the phone across its terminals, you will usually be able to hear it, the noise, in the form of a scratching, or a sound like grease frying in a pan. It may also appear in the form of a click. It may even set up a howl like a microphonic tube, though that is rare.

MICROPHONIC TUBE.—When you have a howl or whistle which continues until the amplifier is shut down and the fader brought to zero, it ordinarily indicates a microphonic tube. The trouble is caused by one of the tube elements being loose. The only remedy is the installation of another tube, but in cases such as this, usually the defective tube will work well in the 41 amplifier because there it is subjected to no vibration, and because any slight noise it may set up will receive very little amplification, whereas in the PEC it gets plenty. If the faulty tube tests well on the milli-amp reading, use it in the 41. If the test is poor, or even only fair, then discard the tube. See former note concerning using faulty tubes in the 41 amplifier.

If we happen to be using a PEC amplifier on a Universal Base, then we have only two stages of amplification, which same are transformer coupled. The method of locating trouble is, however, much the same. The only coupling mediums between the tubes are transformers, and the two stages of amplification are very similar to the third stage already described. True, the transformers may not be all exactly alike as to structural details, but all transformers operate on exactly the same principle, which is the fact to keep in mind when making tests. The structural details may be different, but the action of them all is the same.

These tests are based upon Western Electric equipment, but it is no difficult task to adapt them to any other makes. Those using PEC amplifiers may be treated about as we have described, provided due attention be given to structural differences. For example, tube filaments may be wired in parallel, instead of in series, but that merely alters the details of testing each element, and sets up a condition where the failure of one tube will not affect the other tubes in any degree.

In RCA equipment no PEC amplifier is used. The signal from the photo-electric cell passes through a transformer. Thence it passes to the fader and on to the stages of amplification. There is no great difference in testing as between Western Electric and RCA Photophone. It is a matter of locating the fault in the piece of apparatus, and then locating it exactly in some one part of the piece of apparatus itself.

DEAD AMPLIFIER.—Should we find one of the amplifiers to be dead, we must get busy checking switches, fuses and meters. If the amplifier filaments pull their allotted current, then they are of course O. K. and need no investigation. This will of course include the fuses and switches in the charging panel and the F batteries and their circuits.

With the 6-pole switch closed and both the exciting lamp and amplifier tube filaments taking either less than the current they should, or no current at all, we shall most likely find the trouble on the battery side of the switch. However, if the amplifier tube filaments take proper current, but the exciting lamp filament does not, or vice versa, then something on the amplifier side of the 6-pole switch most likely is at fault.

First of all test the voltage, with a meter, from plus 12 to ground on the 6-pole switch. It should read 12 or more. If the installation be comparatively new and the batteries have just been taken off charge, this test may show as high as fifteen to sixteen volts when the 6-pole switch is open. F batteries that are nearing the end of useful life should test about fourteen volts, though this will depend somewhat on the rate at which they have been charged. If the charge rate was high, the voltage will be higher than if the charging rate were lower.

This is with the 6-pole switch open, remember. Upon closing the switch the voltage will drop down around twelve volts. Should it drop much below twelve upon closing the switch, or if, with the switch open, it is either no voltage at all or below twelve, then immediately take a battery hydrometer reading. If the batteries be old, then take a voltage reading across each individual cell, using the 3-volt scale of the meter. Each cell should show approximately two and one-tenth (2.1) volts. Any cell reading substantially below the others may be considered as having gone bad. It will be good policy to install a new battery at once. The old one **might** hobble along a little while, but it may quit on you at any time, perhaps just when you can least afford to have it do so.

Two (2) volts and below across individual cells when the battery is on open circuit show a discharged battery. To make certain that the battery really is on open circuit when all switches are open, open the circuit right at the battery and insert an ammeter, using the fifteen (15) ampere scale. The 3-ampere scale will show a smaller leak, but first use the larger scale. You thus protect the ammeter, which might be ruined if you used the smaller scale and a heavy current was flowing.

Such a leak is almost invariably a ground. To locate it, inspect all parts of the circuit, including switches, fuses, et cetera. Anything connected with and used in an electrical circuit may develop a ground you know. Especially examine the lead covering on the wires. It may come into contact with the screw with which the wire is clamped. **The negative side is intentionally grounded,** so disregard it entirely.

If you are unable to locate the fault by visual inspection, then you must test with a battery and buzzer, disconnecting elements of the circuit where it is necessary to isolate them for test. To test switches and fuse receptacles, disconnect them entirely from the circuit.

If we have made the test and found the batteries to be O. K., and that everything is free from ground on the positive side of the circuit, then if, with the 6-pole switch open, there is no voltage from plus 12 to ground, we may conclude we have to deal with either an open circuit, or else extremely high resistance somewhere in the circuit, with the chances at least twenty-five to one that it is open circuit, which usually we will find to be a fuse. In fact, when such a condition is encountered, it is always best to examine the fuses first of all. Should the fuses be all right, you will then be compelled to test the circuit at various points for an open or high resistance.

This must be done with both the exciting lamp and amplifier tubes lit, under which condition the current will of course cause a voltage drop across resistance, wherever it may be. You then must test the voltage drop across each piece of apparatus in use in the circuit. Low voltage when the switch is closed and the batteries up to normal is caused by high resistance between the batteries and the switch.

You should test each switch and each blade of a switch. Suppose we find the reading on the battery side of a switch on the charging panel to be 12, but on the amplifier it is only 11. The loss is one volt, and we know the switch is at fault. If we short across each blade in turn with copper, the ammeter hand will move when the one at fault is shorted.

With batteries normal and everything all right up to the 6-pole switch, a low voltage reading on the exciter lamp circuit is caused by high resistance in that circuit, probably the result of a loose or a dirty connection. Test the voltage at the terminal block of the lamphouse first of all. It should be the same as the reading at the 6-pole switch, when the switch is closed. Should it show a bit lower, maybe 11½ volts, the fault is in the circuit inside the lamphouse. Should the voltage be considerably lower than at the switch, you may look for either a loose connection or a very dirty one somewhere between the switch and the terminal block. Don't forget that a poor switch connection can and will set up high resistance.

A low reading on the amplifier tube milliammeter is a somewhat more difficult thing to deal with, for the reason that the circuit is more complicated than that of the exciting lamp; also it is more difficult of access. However, this condition is not likely to be found. The current is so small that a considerable proportionate drop would be necessary to register a low reading on the meter.

If the drop is caused by a loose connection, then either the filaments would probably either go entirely dead or be lighted normally. In other words the contact would either carry sufficient current, or it would be broken completely. This condition may also happen to the exciting lamp, but whether it be that or the amplifier filaments, the condition will be accompanied by a decided clicking noise as the contact makes and breaks because of vibration.

If the milliammeter shows no reading at all, then it is probable that one of the tubes is burned out, in which case find the faulty one by installing a spare in one socket after the other until the set lights up. The tubes are connected in series, you know.

Should the tubes fail to light after you have tried a new tube in each socket, one after the other, then install a whole new set. It always is possible, though improbable, that two tube filaments may let go at the same time. In event you have not a full set of new tubes available, then you may test all the PEC tubes in the 41 amplifier, or if that is impractical because of a show being in progress, then try them with dry cell hooked in with the 15-volt scale of the meter in series with the filament of each tube. If there is a reading on the meter, then the filament is O. K. In making this test, connect to the two large diameter prongs. The small ones are the grid and plate.

In event you have tested the tubes and found them all right, yet there still is no filament current, test the voltage on terminal lugs 1 and 3 by the bakelite strips from which the carrying springs are supported. Should this show no voltage, then short the meter with your screwdriver blade, leaving the voltmeter attached to lugs 1 and 3 while you do this. If current flows by thus cutting out the milliammeter, it indicates that it is defective and you must cut it out of the circuit until another can be installed. If this has no effect, then try shorting the rheostat. If you get current, then it is defective and must be cut out until you can get a new one installed, **but** this you may find impractical. If you have been running with the resistance almost all out, then you may be able to do it, though the results will not be the best.

Given a little time you should be able to fix up some iron wire resistance which will serve, though probably poorly, as a substitute. On the whole it is well to have one of these rheostats on hand, ready for immediate use in such a case as this.

Mr. Schroeder suggests the following. It is given without comment, except that I would myself prefer an iron wire coil hung beneath the lamphouse, with one end attached to one rheostat terminal and the other reached by a wire attached at one end to the other rheostat binding post, with a strong paper clip attached to the other. You then could alter the current at will, though rather clumsily, by moving the clip along the coil.

Mr. Schroeder's plan is: "In case the current goes higher than 280 mills, it must be reduced. Place the rheostat bar in approximately the position it has been when 270 mills was registered. Note the position of the sliding contact on the wire. Cut off from the good portion of the resistance wire an amount approximately equal to what was in use when registering 270 mills, allowing a few extra turns to compensate for possible error in estimating exact position of sliding contact arm.

NOTE.—Be certain to cut the wire so that the portion or wire heretofore unused will come into service.

Having done this, next take out the insulating strip with the wire on it. It may be hard to get out if it was originally well cemented in place, but usually not much trouble will be encountered.

Cut the strip opposite where you cut the wire. Unwind a few turns of the wire and fasten it under one of the terminal screws of the rheostat. Fasten the other end the same as it was before you removed the unit from the strip and wire.

Now, when all this is done, light up the amplifier and take the milliammeter reading. If the reading is too low, then cut off a bit of wire and try again. Repeat until you get the right reading, though if the reading is 250 it will be better to leave it that way, rather than take a chance of getting it too high.

Should you get no voltage by shorting the rheostat and milliammeter, then you will probably find a broken or disconnected wire between these instruments and the 6-pole switch. It is even possible that a wire might be broken or burned off elsewhere, but extremely unlikely. If after you have done all these things and still the trouble is not located, then you must test each wire with your battery and buzzer. Just touch the terminals of the battery and buzzer to the binding post at either end of the wire you are testing. No ring means broken wire. A ring of course means O. K.

AMPLIFIER AT FAULT.—In case we get full voltage across terminals 1 and 3 on top of the amplifier, it is evidence that the fault lies in the amplifier itself. In this case, connect a buzzer in series with two dry cell batteries, because it will be necessary to test through a 24-ohm resistance, and if the buzzer requires considerable current, as most buzzers do, one battery cell may not serve to operate it. In connecting be certain that you connect the positive of one battery to the negative of the other.

When your tester is connected up, try it by bringing its terminals together.

NOTE.—Always test a buzzer tester in this manner before proceeding to make actual tests, but if a meter is in the circuit, don't do it without resistance in series, else you may ruin the meter. A buzzer will serve for resistance in that case. Just touch the terminals of your testing circuit to the terminals of a buzzer.

Having your tester ready as above, attach the terminals to two pieces of No. 8 wire long enough to handle conveniently. Wrap these wires with insulating tape to within half an inch of their ends. These wires are to shove into the holes in the tube sockets—into the two large ones, not the small ones. The small ones are the plate and grid. The large ones are the filament connections.

When everything is ready, remove the tubes from the amplifier and, with the 6-pole switch open, place one terminal of your tester on a rheostat terminal and the other in one of the large holes in the socket furthest away from you, presuming you to be standing on the working side of the projector.

If you get a buzz, this portion of the circuit is O. K. If no buzz comes, then place the terminal that was in the large hole in the other large hole of the same socket. A buzz shows the part to be O. K. No buzz proves to us that the circuit is open somewhere between the socket and the terminals on top of the amplifier. We test the second hole of the socket after not getting a buzz from the first one, for the reason that the first one might be the one connected with the center tube. Remember that the circuit is all right if we get a buzz from either of the holes of any one socket. On the other hand, if no buzz can be gotten from either hole, then the circuit is open.

WARNING.—A buzz at both holes of a socket means that the same is shorted, though it may be either at the socket or somewhere in its circuit.

In Western Electric equipment, that part of the circuit we have just been testing consists of a small, flexible connection from the terminal lug to one of the springs which support the amplifier, the spring itself, another flexible lead reaching from the spring to a lug on the bakelite strip below, and a wire from the lug to the socket.

Having made the test and found an open circuit, remove the amplifier and carefully inspect this portion of the wiring. **Before removing the amplifier,** be sure to so mark all wires that you may get them correctly re-attached when you are through.

To test the amplifier after its removal from the projector, proceed as already directed, except that instead of placing one test terminal on the rheostat, we now place it on the positive terminal on top of the amplifier.

Assuming our first test to show everything to be O. K., we place one test terminal in the hole where no buzz resulted and place the other terminal in one of the large holes in the center socket. If no buzz results, try the other large hole. This test includes the 24-ohm resistance. If no buzz results from this last, then place the testing terminals directly across the 24-ohm resistance. A buzz of course indicates the resistance to be O. K., but that one of the circuit wires is "open." No buzz across the resistance of course shows the resistance to be burned out.

Next we go to the next and last tube. There is nothing but a wire between this tube and the center one, but between it and the negative terminal on the amplifier is a 4-ohm resistance, which must be tested the same as directed for the 24-ohm one.

It may have occurred to the projectionist that a battery and voltmeter would do as well to test with, but this is not true for the reason that, because of the fact that a voltmeter draws very little current, it would show a good reading through a high resistance, such as, for example, a badly corroded connection would offer. When using a battery and buzzer you would get no buzz, or only a very weak one, through such resistance.

True, it is possible to use a battery and flashlight bulb, or even a 110-volt bulb hooked to one side of the power circuit—the positive—but the battery and buzzer is in every way better and safer.

THE FILAMENT CIRCUIT.—It should be understood that the only trouble the filament circuit, located inside the amplifier, falls heir to is a broken wire, a short or ground or burned out resistances. No instruction is necessary as to repairing a broken wire, except avoid acids in soldering. Use nothing but rosin core solder. Clean the metal **thoroughly.**

A short or ground will show up either on the milliammeter or in the form of blown fuses. If you suspect a short, it is only necessary to test from each socket to all points it connects to—to all other points in the amplifier filament circuit. From any one socket there are only two points which will give you a buzz, namely, from one hole to the next place further on in the circuit, and from the other hole to the next place in the other direction.

For example, testing from the center socket to the plus 12 terminal should give no buzz. If it does, then there is a shunt path of some sort around the socket. Had the tube been left in its socket just this sort of condition would obtain. That is why we remove them before testing—that and the further fact that we could not test the holes with the tubes in.

As to a ground, every projectionist knows how to test for that. See page 356, Volume 1, but it must be remembered that the negative 12 terminal is normally grounded by intention, hence you will get a buzz from one hole in the socket on the right of the amplifier to ground. That is as it should be.

SHORTING OUT RESISTANCE.—In case of emergency you can get along with the 4-ohm resistance shorted out, but it is not a good condition. Better keep one of those resistances in stock. It is possible to connect two flashlight bulbs in parallel, and use them in lieu of the 4-ohm resistance, as such bulbs usually have about 10 ohms resistance. However, we do not recommend such makeshifts. Better have spare parts in stock.

In lieu of the 24-ohm resistance it is possible to use two of the flashlight 10-ohm bulbs connected in series, but it is a poor makeshift at best. There are other makeshifts, but we do not care to advise how to do a thing wrongly, even to "get by." "Get by" by having proper spare parts, and thus do the job right.

WARNING.—In using a battery and buzzer or a battery and voltmeter for testing, never attempt to pass the battery current through any transformer windings except those which normally carry plate current. The reason for this warning is that some transformer windings are not designed to carry direct current, and the magnetic characteristics of the transformer may be upset if direct current is passed through them. **Also remember** that the resistance of most amplifier transformer windings is very much too high for a buzzer to operate in series with them, and that if a voltmeter be operated in series with such a winding, the high resistance may and probably will prevent the meter from registering the full battery voltage.

KEEP DIAGRAM BEFORE YOU.—When testing, the projectionist should always keep the wiring diagram of the apparatus before him. Remember that if you have removed the PEC amplifier from the projector, then while it is out it does not conform to what is shown in the wiring diagram for the reason that the two transformers remain attached to the projector, which has an effect upon plate circuits V2 and V3, as well as the grid circuit V3. For this reason all possible tests should be made before removing the amplifier, since thus you may determine whether the seat of trouble is in the external circuits or in the amplifier itself.

Should you find the trouble to be in the amplifier, you had better proceed with the testing until the circuit in which the trouble lies is definitely located, though this does not mean that you must locate the particular part itself. Each circuit in the amplifier, treated by itself, is very simple and easily tested. When the trouble breeding circuit is located, it is an easy matter to locate the particular part of the circuit which is upsetting things, whereupon it is likely the projectionist will be able to effect at least a temporary remedy with material at hand.

Starting with the assumption that no sound comes through the PEC amplifier, though the tubes and filament circuits test out O. K., it is more than likely we shall find the trouble in one of the plate circuits, remembering, however, that the fuses, PEC batteries, et cetera, are a part of the plate circuits.

Test voltage at the 6-pole switch on the wall first. In event of failure to get a reading on one or more of the terminals, then test the voltage at the batteries. If the voltage there is O. K., then we may conclude that one or more fuses are either blown or are not making current carrying contact.

With your battery and buzzer, test each fuse. If they all test O. K., then find the open by removing the fuses one by one, cleaning and tightening the contacts. Should a fuse blow immediately, with the 6-pole switch in open position you may look for a ground or short between the batteries and switch. Of course if the test shows the battery defective, then replace the battery.

WATCH THIS.—Sometimes, unless one watches closely, the screws under which the wires are clamped on the terminal strip in the battery box may extend through the strip and come into contact with the lead covering of the wires underneath. Make certain before tightening these screws that they are not long enough to do this, as such a condition grounds the battery.

REPLACE BATTERIES.—Any battery testing as low as 40 to 42 volts should be immediately replaced. When this point is reached, a battery drops off very fast and you are taking needless risk in using it longer.

OPEN OR SHORT.—If the batteries and fuses test out O. K., then we may seek an open circuit, which will most likely be found at the terminals of either the battery box or the switch.

Having everything O. K. up to the 6-pole switch, with 45, 90 and 90 volts, or possibly one or two volts less, close the switch and test the voltage at each tube. Connect a wire from the 150-volt voltmeter terminal to ground and to the positive voltmeter terminal attach a wire, insulated of course, long enough to reach the parts to be tested.

Test each tube socket by placing the end of the test wire in contact with the plate terminal of the socket. For V1, V2 and V3 the voltmeter readings should be approximately 10, 35 and 65, respectively.

NOTE.—These voltage readings were obtained with a Weston Model 280 voltmeter. The readings will be different with any voltmeter having different resistance, though the average meter will be found to have resistance practically equal with the Weston 280. Of course a high resistance voltmeter (1,000 ohms per volt) will read much higher. On the other hand, using one of the small pocket meters employed for testing dry batteries, et cetera, would result in no reading at all on the first tube, and very low ones on the other two. Such meters draw very high current, causing a heavy drop in the resistance or in the transformers, which results in low voltage readings. **You must know your meter** before attempting to make such tests as these.

Using a Weston 280 voltmeter or its equivalent, 45 volts on V2, or 90 volts on V3, shows the transformer primary to be shorted. If it is the V2 at fault, then the input transformer is indicated. If it is the V3, then the output transformer is at fault.

WARNING.—Although it is almost impossible, still this same condition could be set up by a wire or some current-carrying object coming into contact with terminals 2 and 5 of the input transformer.

It also is possible for either half of the primary to become shorted, which would result in a reading of between 35 and 45 on V2 and between 65 and 90 on V3. A short of either the whole or half of the primary would manifest itself in visible form at the terminals of the two transformers.

A ground on the battery side of the coupling of either the resistance or the transformers would blow a fuse in the PEC battery box when the amplifier switch is closed. A ground in the wiring between the switch and the amplifier will blow a fuse.

Should this occur, open the switch and replace the blown fuse, the location of which will of course indicate the circuit at fault, except the fuse on the 45-volt wire, which supplies current for both V1 and V2.

TO FIND THE GROUND.—With the switch in open position, connect the positive terminal of the voltmeter to one of the 90-volt terminals of the switch, on the live side, of course. To the 150-volt negative terminal of the meter attach a wire long enough to reach to all parts of the PEC amplifier. The fuse itself has already indicated the faulty circuit, but for additional check, touch the negative lead from the meter to the 45, the 90 and the PEC terminals on the dead side of the switch. Any terminal showing a reading is connected to the circuit that is grounded.

Let us assume the PEC terminal on the switch to show a reading when the test is made. We may then either look for another ground, or make another test to further locate the trouble before the actual search for it begins.

First, open the transformer housing compartment under the PEC amplifier on the left side of the projector. Disconnect the wire from the PEC terminal. Test the wire and then the terminal itself. The meter reading will indicate in which direction the trouble lies.

Inspect the wires so far as they are visible, looking carefully for spots where the insulation may be defective, especially where the wire goes around a sharp bend. Also make sure that no strands of wire or other current-carrying objects make contact with any of the terminals of the clip on which the coupling resistance is mounted. Carefully inspect the spring which carries the current from the stationary terminal strip on top to the one below. It is the one connected to lug No. 7 on top of the amplifier.

If the trouble be in this section and you experience trouble in locating the exact point, unsolder the wire from lug No. 7 and test both it and the lug. A reading on the lug test indicates a ground in the amplifier itself.

If the wire test shows a reading, then the ground is between its upper end and the terminal in the transformer compartment, assuming of course that you have disconnected the wire in the compartment before testing.

Should you be unable to locate the fault, or should it lie in conduit or BX and there is not time to locate and repair it, you may effect temporary repair by connecting an insulated wire between lug No. 7 and the terminal in the transformer, disconnecting the old wiring, of course. No evil will result except that you may, and most likely will, pick up more or less noise from other circuits. To minimize or even possibly eliminate this, use shielded wire if you have or can get it, grounding the shielding, but remembering that the ground connection must be a thorough one. A poor or loose connection to ground will set up more noise than the well grounded shielding would eliminate.

In case no shielded wire is available, then use a twisted pair of wires, connecting one of the pair to supplant the disconnected faulty wire and the other to ground. In fact it is well in such a case to ground both ends of the ground wire. In some cases grounding one end of the wire will seem to be of slight assistance in noise elimination, whereas by disconnecting that end and grounding the other end all noise will cease. It is a queer and rather tricky proposition.

CONDENSER NOISE ELIMINATION.—If a condenser is at hand, it may be utilized to eliminate noise in the before described connection. A micro-farad is excellent for the purpose. Connect one of its terminals to the No. 7 lug at top of amplifier and its other terminal to ground; also ground the condenser container itself.

Lay the condenser inside the amplifier compartment; both it and its wiring are then shielded.

WARNING.—Exercise great care in using a condenser thus in other circuits. In some it may kill all sound. In others only the high frequencies.

Should the 45-volt terminal show a ground, it may be between the switch and the transformer compartment. If beyond this point, it may be either in the V1 plate circuit or in the V2 plate circuit. Unsolder the wire on terminal No. 5 on the input transformer. If the ground still shows up, then it is either in the V1 plate circuit or in the wire we have just unsoldered. The coupling resistance of this plate can hardly become grounded, therefore it is safe to assume the ground to be in the wiring, in the spring which is connected to No. 4 lug or in the socket.

A ground in the plate end of the input transformer may show a low reading on the testing voltmeter when the test lead is touched to the lower end of the primary. It therefore is best to test the plate terminal before testing the other end. In this way a ground near the plate terminal will give a fairly high reading—in fact, a reading very close to the full battery voltage, in this case about 45. Western Electric equipment, remember.

Should we find a ground in the transformer primary, break the connections in the center of the winding, that is to say, at terminals 1 and 6. We may then test to see which half of the winding is grounded. If the part from 2 to 1 shows fault, take the wire soldered to lug No. 2 and solder it to No. 6. Leave disconnected the wire which formerly connected Nos. 1 and 6.

If it is the other half that is grounded, solder the wire that was soldered to lug No. 7, already disconnected to find which half the trouble is in, to lug No. 1, again leaving two parts disconnected, namely lugs No. 1 and 6.

Using only half of the primary, temporarily of course, we will lose a good deal in the amplification, especially of the lower notes. However, no other trouble will result and the connection may continue until a new half can be installed in place of the faulty one.

TROUBLE AT 90-VOLT TAP.—Trouble at the 90-volt tap indicates fault in the V3 circuit, which is very similar to the V2, except that the voltage is 90 instead of 45. Also the transformer is called the "Output" instead of the "Input" transformer. The lugs are differently numbered also.

The testing method is exactly the same; however, do not forget that we must not use the same lug numbers, but **corresponding lugs** instead. Five (5) is the input battery terminal in the input transformer, which lug of the output is No. 7. You may clear this all up by examining the wiring diagram on the cover.

Should it ever happen that both halves of the primary of the input transformer become either grounded or "open," which same may happen if the part between lugs 2 and 1 become grounded, the rush of current due to the ground burning out the section between lugs 6 and 5, the transformer should be replaced with a new one.

WARNING.—Do not attempt to substitute transformers from other apparatus. Use only the transformer supplied for the purpose by the manufacturer of the equipment.

In plate circuit V1 we find a resistance. Should this burn out or become otherwise defective, break its connection with the socket and break the plate connection to No. 2 terminal at the top of the amplifier. Attach the wire from No. 2 terminal to the plate terminal on socket V1, which cuts out the resistance and V2.

If the input transformer is at fault, disconnect the wires from lugs 2 and 5 at the top of the amplifier. Solder the wire which attached to lug 5 to lug No. 2, which cuts out the input transformer and V3, after which V2 should have an altered grid bias. This is remedied by disconnecting the wire connecting terminal No. 7 on the output transformer and the 90-volt terminal on the strip just below it. Disconnect it from the 90-volt terminal and attach it to the 45-volt terminal. If you have sufficient amplification thus, all right. If not, remake the connection as it was before, and run that way until a replacement can be obtained.

WHEN AN OUTPUT TRANSFORMER GOES BAD.—In such a case, with no transformer with which to replace it, the only really practical recourse is to use the transformer on the other projector. This may be done in either of two ways.

The first way is to use the photo-electric cell only, on the amplifier that is out of commission, conducting the signal from here to the PEC amplifier of the other projector. Disconnect the lead from the photo-electric cell of both projectors. Secure a double throw switch of any sort. Connect the good binding post of the good amplifier which formerly connected to the photo-electric cell to the **center** binding post of the switch blade, if it be a single-pole switch—or to the center binding post of one of the blades if the switch has two or more blades. Now connect the photo-electric cell of each projector to one of the other contacts of the blade (it is a DT switch, remember) and merely by throwing one switch over you will be using one amplifier for both projectors. For making the connections use only lead covered wire, if it can be had. If not, then BX covered wire. In either case be sure to thoroughly ground the lead or BX. If you don't, you will probably be amazed at the noise the wires will pick up. You probably will get some anyhow. Before changing from one projector to the other, **be sure to have the fader on zero.**

NOTE.—On such a connection we may be able to eliminate some noise by grounding one amplifier frame to the other. Attach the wire by means of the same screw which grounds the lead of the photo-electric cell in each amplifier.

The second method is to use both amplifiers, but to arrange to use the output transformer of one for both. This may be done as follows: First, break the connection at terminal 5 on top of both amplifiers. Second, using a lead covered wire if available, if not, then a BX wire, connect the wire removed from terminal 5 of the amplifier having the faulty transformer to one end of one blade of a double-throw switch. Third, using the same kind of wire, connect terminal 5 of that amplifier to one contact point of the same switch blade. Fourth, connect terminal 5 of the other amplifier to the other contact of the switch blade.

This completes the job except for grounding the wire sheathing, which is very important. You then, merely by throwing the switch blade, use the good output transformer for both amplifiers.

When using this plan, the signal will be at a much higher level than at the photo-electric cell, hence will not pick up so much noise. It may even be possible to get along with unshielded wires, but I would not try that, I think.

NOTE.—If no double-throw switch is available, two single-throw switches may be utilized. Just connect the back end of one blade of each switch together by means of soldered wire. You may then connect up and open one and close the other. The effect will be the same as a DP switch.

As a rule the grid circuits of the film amplifier are not a source of trouble. Oil mixed with dust smeared across the bakelite strip upon which the 10-ohm resistance is mounted often causes current leakage and therefore trouble. Watch this closely and keep it perfectly clean. A very thin deposit will serve to cause loss in amplification.

Should you suspect one of the grid circuits to be faulty, remove the tubes, close the 6-pole switch and with a voltmeter test from ground to the grid connections of sockets V1 and V2. A positive voltage on either of these sockets is evidence that one of the condensers is shorted, or that a shunt circuit has been established around the plate circuit to the particular grid in question.

The fault may be located by disconnecting the condenser and making another test from grid to ground. If the grid still is positive it is evident that the condenser is all right, but if the grid reads zero, then the condenser is shorted.

Do not lose sight of the conditions under which the test was made. The grid was first found to be positive, but as soon as the condenser was disconnected it was zero, which proves the condenser to be shorted.

If everything is as it should be, then the grid would be zero, both with the condenser in and out of the circuit. This is evident when we remember that the test was made with the tubes out. No current then can flow, hence there can be no bias on the grid, hence no voltage.

The remedy, of course, is to replace the condenser with a spare of the same capacity, which should be kept always at hand.

CONDENSER.—It sometimes happens that a condenser will, besides becoming shorted, also be open circuited, though this is very rarely the case. It may be caused either by rough handling or by a defect in the instrument. However, in a moulded condenser such as a .006, it can only be caused by defective material or poor workmanship during the process of manufacture.

To test a .006 for open circuit, disconnect both leaks and remove the first tube, then using a battery and head phones, test across the condenser. A click indicates no open circuit. Repeat the test to find out immediately whether or not the click was due to a short. A second click indicates a short, though in event the condenser is discharged before the second test is made, which may be done merely by touching both terminals with the fingers, you should get the second click anyhow.

To test C2, open the 6-pole switch and remove the first two tubes, namely V1 and V2. With head phones and battery in series, place one lead in the hole in socket V2 into which the tube grid prong goes. Place the other lead on the plate terminal of V1. A pronounced click at contact indicates that the condenser is not open circuited; also that the wires from V1 to V2 are not broken.

However, should the click be faint, we may know the condenser is open circuited. The faint click results from the residual capacity of resistances R4 and R5 and the wiring involved. There is no danger of mistaking the two, as the condenser is of considerable capacity, hence will produce a much louder click than will the capacity of the apparatus.

THE 10-MEGOHM LEAK.—Noise in one form or another almost invariably results from trouble in the 10-megohm leak. The easiest and quickest way to test the condition of the leak is to replace it with a spare which is known to be in perfect condition. Another way is to short the two clips by which the leak is supported.

WARNING.—If you do this, use a well insulated shorting tool, or hold the tool between two pieces of rubber. If shorting stops the noise, then either the leak itself is faulty, or its supporting clips are dirty. However, before testing make sure that the clips make clean, firm contact with the leak, bending them together if necessary.

A poor contact either here or anywhere else in the amplifier will set up noise, or may cause the sound to go entirely dead intermittently.

WARNING.—In a grid circuit a contact may be tight; also upon examination the contact surfaces may look perfectly clean, still there may be a thin, invisible insulating deposit; therefore before assembling a grid leak it is well to rub the contact surfaces with 00 sandpaper, some of which should be kept in stock for the purpose. We are at this point dealing with very weak currents, hence it does not require much resistance to affect them. After sandpapering a contact, always **wipe it clean** with a clean cloth—not with your fingers. If you fail to do so, you may make the condition worse instead of better, by reason of grit left upon the surfaces. The holes in the 10-megohm mounting clips may be carefully and lightly scraped with the small blade of a knife.

TO TEST FOR GROUND IN .006 CONDENSER. —To test for ground in connecting the .006 condenser, the grid terminal of V1 and the clip in one end of which the 10-megohm leak is mounted, and the clip itself or the terminal of the socket, a buzzer and battery is best, testing from grid terminal of V1 to ground. No buzz, O. K.; a buzz means a ground.

The clip holding the other end of the 10-megohm leak must also be tested to make sure the wiring is continuous. This test is made between clip and the ground. You should get response from the buzzer. No buzz means an open circuit, which you then must, of course, find and repair.

Having already tested and found the circuit between condenser and grid terminal of V2 to be in good order, we now must test the circuit from the grid terminal of V2 to the filament; also test for grounds in the circuit connecting C2 and the 100,000-ohm resistance R5 and the grid terminal.

We should test for ground first, using battery and buzzer. Test from grid of V2 to ground. It is unnecessary to disconnect R5. The buzzer will not ring through

100,000 ohms resistance. A buzz shows a ground, which you must find and repair.

TEST FOR CONTINUITY WITH HEAD PHONES.—Test from grid of V2 to ground. A click indicates circuit to be O. K. You should get a click upon breaking connection. That is quite all right in this case.

Using battery and head phones, test for continuity from grid of V3 to ground. If there is no click, then the circuit is open. If circuit is O. K., you will get a click both at making and breaking the contact.

Usually a ground in either of the grid circuits of the first two tubes will not cause trouble. However, if they exist, it is easy to find and remedy them.

A 10-megohm leak which is faulty must be replaced with a spare of the same value, though one of somewhat different value may be used in case of emergency. R5 is unlikely to give trouble. Should it do so, it may be replaced temporarily with a grid leak of the same value, though should this be done a mounting must be provided, as wires cannot be attached to the leak itself. If you attempt to do so you will merely ruin the leak. The small resistance strip inside is attached by means of a metal which has a very low fusing point. Any attempt to solder wires to the leak would probably melt this metal, thus disconnecting the resistance and rendering the leak worthless.

Should trouble occur in the input transformer secondary winding, half the faulty secondary winding may be cut out. Previous instruction regarding cutting out a part of the primary winding tells how to do it. Should the entire secondary be "gone," then you must either replace the transformer or cut out one stage of amplification.

We still have the question of low volume and distortion due to the PEC amplifier, but we have discussed almost all causes of these two troubles when treating of a dead amplifier. Oil soaked wire sets up what seems to be a very mysterious volume loss. Should you suspect this, have the service engineer test the condition of the wiring. When you call him, if you do, advise him as to what is wanted as he must fetch a suitable testing meter.

The disc equalizer itself should give no trouble. The device consists of a resistance, an inductance and a capacity. An open circuit in the equalizer or in the associated wiring will produce the same result as cutting out the equalizer, which is what really happens. This only causes a greater amount of surface noise to come through, but will otherwise not affect the show.

A ground occurring in the equalizer will either cause a loss of volume or completely kill the sound, depending on where the ground occurs and on what terminal of the equalizer is connected to the system. No. 4 terminal is always connected and is also grounded through the fader. This must be kept in mind during the testing, unless the wire is removed from terminal No. 4, but there is no need for doing this. If the condenser becomes shorted, it grounds the lower end of the inductance.

A ground in the wiring to the equalizer kills all the sound. Complete loss of sound due to grounds in the wiring or in the equalizer is easy to diagnose. A test at the reproducer with a pair of phones will show no sound to be present. Disconnect the reproducer and test again. This time the signal will be heard. The only thing that will cause such a condition is a short circuit (or ground) across the reproducer, and its location will be somewhere between the reproducer and the fader, or in the fader itself.

From this point there are a number of ways to proceed. Perhaps the quickest is to throw over to film, light the film amplifier on the **same** machine that is being tested. Now with the fader up, pass your finger up and down through the exciter lamp beam. A series of loud clicks shows that the trouble is not in the fader. An absence of the clicks is not a positive indication that the fader is at fault, but suggests further testing. Trouble in the film disc transfer switch can kill both the film and disc on the one projector, and it is possible for it to affect both projectors, though this is quite unlikely.

Probably the best step to take next is to disconnect the equalizer. If this clears up the trouble, the equalizer is at fault. Should the trouble still remain after the equalizer is cut out, disconnect the wires at the fader input corresponding to projector causing the trouble. With the switch on the disc side and the reproducer again connected, play a record and listen with the phones hooked to the wires that were removed from the fader. If you get sound at this point the fader was the cause of the trouble. We will presume that the fader was O. K. and the sound is not present at the ends of these two wires. Disconnect the reproducer, then hook the voltmeter and battery across ground and one of the wires that were removed from the fader, then from ground to the other wire. With the film disc switch in the off position a reading on the meter indicates a ground in the wiring between the fader and the film disc switch, or in the switch itself. The ground can probably be located now by close inspection, though it may become necessary to unsolder the wire at the switch and again test the wire and the blade of the switch separately.

No reading from ground to either of the wires shows this part O. K. Move the switch to disc. A reading from ground to one of the wires indicates a ground in the switching panel, the wire going to the reproducer, or the one going to the equalizer panel. The wires from the reproducer and from the equalizer come together in the switching panel. They can be separated here and tested individually.

An open circuit in the wiring between the reproducer and the film disc transfer switch is easier to locate. When testing across the reproducer with the phones, sound is heard. Obviously, a record must be played while making the test. Testing with the phones at the input to the fader, no sound will be heard. Inspect and clean the contacts on the blades of the film disc switch, also the two switches at the top of the fader. A test with the phones at the input to the film disc switch will indicate whether the trouble is between this point and the reproducer or between here and the fader. If the trouble is in the line from the pick-up to the switch, test each of the two wires for continuity, using battery and voltmeter or battery and buzzer. If you use the battery and buzzer, be sure the reproducer is disconnected from the circuit, so as to eliminate the possibility of sending a current through it that might tend to demagnetize the permanent magnet.

The circuit from the transfer switch to the fader can be tested in a similar manner, but in this case it is best to use a battery and a buzzer. The buzzer is used in order to send a comparatively large current through the contacts of the switches, so that any high resistance will be discovered. The voltmeter draws so little current that resistance at the contacts would not show up unless they were so bad that it was nearly an open circuit. Use only 1½ volts to test, or, if using a storage battery, 2 volts. Be sure that the film disc switch is on disc and that the two keys at the top of the fader are in their proper position.

When working on these switches, be very careful not to bend any of the blades, unless it is seen that they do not touch each other properly; if such is the case, proceed very slowly and be sure of what you are doing, for if you should get two or three of the blades all out of shape you are in for a world of grief.

In testing the film attenuator and the circuits associated with it, i.e., all the wiring and apparatus between the output of the film amplifier and the input to the film disc transfer switch, it is very necessary to see that the output of the amplifier is not shorted at the 6-pole switch. The output is marked on the switch. It is connected to the long stationary contacts that are bellied out, and to the corresponding movable blade. Sometimes these two are in contact when the switch is in the off position, and on some switches they are still in contact if the switch is not entirely closed.

The methods of testing the circuits between the PEC amplifier and the fader are quite similar to those used when looking for trouble located between the disc pick-up and the fader. Shorts or grounds again kill the signal. One side of this circuit is also grounded in the fader. The point to remember when testing for continuity is that an open circuit in the line going to the attenuator kills the sound, whereas an open circuit in the line connecting the disc equalizer does not. In the case of the equalizer two wires are tapped to the line at the film disc transfer switch and then run over to the equalizer panel. From the film amplifier the ouput is taken to the attenuator and then a line is run back to the transfer switch, so that a break here results in no sound. The continuity test must be made either with the voltmeter or with phones, using a battery with either of them. Battery and buzzer will not work because not enough current will flow through the resistances of the attenuator, which are in series with the test circuit, to actuate the buzzer.

The line from film amplifier to the attenuator can be tested for grounds and shorts with a battery and buzzer without disconnecting the attenuator. This also applies to the line from the attenuator to the transfer switch, the switch itself and the wiring from the switch to the fader. If you intend to use a battery and voltmeter to make this test, you must first disconnect the attenuator and the output transformer in the film amplifier, then place the film disc switch in the center position if testing only this far. If you also want to test the wiring from here to the fader for grounds you must disconnect the wires at the fader which are coming from the particular machine being tested. This is because the meter will give a reading due to the connection caused by the circuits across the line, that is, the output transformer, the attentuator, or the fader.

It isn't likely that the attenuator itself will become grounded or shorted, but should you wish to test for this, first disconnect the input and the output, and take off the small bar that is used to make the adjustments.

Now you can test with battery and phones or battery and voltmeter. Test from one row of screws to each of the other rows in turn. Then test the other two rows. This will show if a connection exists between the different rows, which should not be the case when the connecting bar has been removed.

To test for an open circuit disconnect the input and output and remove the bar. Test with battery and voltmeter. From one of the input terminals a wire runs directly over to one output terminal. Test from one input terminal to the output terminals; if you get no reading, test from the other input terminal to the output. On one of these tests you should get a reading. Next test from one of these terminals to the three rows of screws. There should be a circuit from the terminal to one row of the screws. Now see that you get a reading at the last screw on each end of this row. When you cannot get a reading by testing from the input or output to any row of the screws, there is a break in the wiring from this series of resistances to the input or output. If there is an indication of a circuit from one of the end screws but there is no voltage at the other end screw in the same row, one of the resistances has become open circuited. To determine which one it is, begin at one end of the row and test from the first screw to the one next to it. Then from the second screw to the third, and so on until you get to two across which you get no reading. This is the open resistance, and can be temporarily cut out by putting a small wire across the two screws. Sometimes the open coil can be cut out by placing the bar to one side of the break or the other. Of course this can only be done when it does not throw the adjustment too far off of normal.

To test the next series of resistances, test from the input terminal that was not part of the circuit just discussed, to one of two remaining rows of screws. The procedure now is the same as that described.

The last resistances are connected to the remaining output terminal. Proceed as before.

When the fader is suspected, first see if the keys at the top are in the proper position. Next, throw over the key at the left, to the side that is causing the trouble. If this clears the trouble, it shows that the cause lies in that side of the fader. When there is still no sound, the trouble is probably in one of the two keys or in the wiring between them and the fader. If this is due to a ground, no sound will be heard at the input terminals when listening with the phones, but on removing the two wires from the input terminals, and connecting the phones to the wires the sound will come through O. K. If trouble is an open, sound will be present with wires on the terminals.

To locate the ground, first disconnect the wire that is fastened to the ground stud in the fader. Next, with a battery and voltmeter, test from ground to various blades of the keys, separating the contacts with a piece of paper or disconnecting the wires, as required, until the actual part or wire that is causing the trouble is discovered.

When sound is present at the input but not at the output, this will be caused by an open anywhere in the fader or the keys, a ground in the output end of the fader or in that part of the left-hand key used to switch from the fader to the emergency pad, or in a ground or short between the fader and the input transformer in the 41.

Throw the left-hand key so as to cut out the dead side of the fader. If the trouble is in the fader, this will restore the sound. When the key is defective or a ground exists beyond the fader, the set will still be dead. Take the two wires off of the output terminals, and test with the phones on the terminals. Sound coming through now shows the trouble was outside of the fader.

Assuming that there was still no sound, test for grounds as before. Should a ground be present, it will be in the left-hand key, the wiring, or in the fader proper.

Finding no ground, test the circuits for continuity.

All these tests are made with battery and voltmeter. The continuity tests are made somewhat as those described in regard to the attenuator. If a break exists in the series of resistances, you can bridge across the two taps temporarily with a wire. The only probable trouble in the fader are dirty contacts, i.e., between the fader disc, contact studs and their respective wiper contacts; and, once in a while, faulty key contacts.

The filament circuit of the 41A amplifier is similar to the one used in the photo-electric cell amplifier. The three tubes are connected in series. On the negative end is a resistance, producing a drop from which the grid bias is obtained. On the positive end is a switch, a rheostat and a meter. Since the filament circuits of the two amplifiers are very much alike, tracing trouble in the 41 amplifier filament circuits is to all intents and purposes the same as has been set forth for the photo-electric cell amplifier.

To supply a current reading in this amplifier there is a meter in each of the plate circuits. This very often is helpful in determining in which stage of the amplifier a trouble is located. Before checking the plate current, always check the filament current, adjusting it to 270 mils if it does not already stand at that value.

When the plate current under test, with the possible exception of a shorted input transformer in the 42A amplifier, is all right, then the grid circuit of the tube under test probably is also all right.

When the tube is taking its proper plate and filament current, there can be certain troubles only in the grid circuits, in case of V1, namely an open in the secondary circuit of the input transformer; an open in the potentiometer, which is the gain control across the secondary; a break in the wiring between the secondary and the potentiometer, or a ground on the high side of either of these. Incidentally, a ground on the low side of either of these might cause trouble, but probably would not. A ground here would short the 100,000 ohm resistance R1 and the worst results to be expected from this would be uneven amplification at different frequencies. This is very unlikely, however, as the various circuits in this amplifier are very well filtered.

A grounded grid lead or a ground at the grid terminal of the socket, has the same effect as a ground on the high side of the secondary or the potentiometer. Obviously a ground at any of these points will result in no sound, except the ground between the transformer and R1.

With an open potentiometer the sound usually comes through all right, unless the break happen to be above the point where the wiper arm happens to be, in which case you can shove the gain up and thus again having sound. The potentiometer should, however, be replaced or else repaired as soon as possible, because while jumping across the break will cause the potentiometer to function again, still it has the effect of putting the wrong impedance across the secondary of the transformer. The jumper should, therefore, be used only in cases of emergency.

An open transformer secondary usually results in loss of sound. Though occasionally the sound will come through, its volumn will be very low.

You should have small difficulty in locating any of these faults, but if you are in doubt, examine the directions for dealing with similar circuits in the photo-electric cell amplifier. They will serve you perfectly.

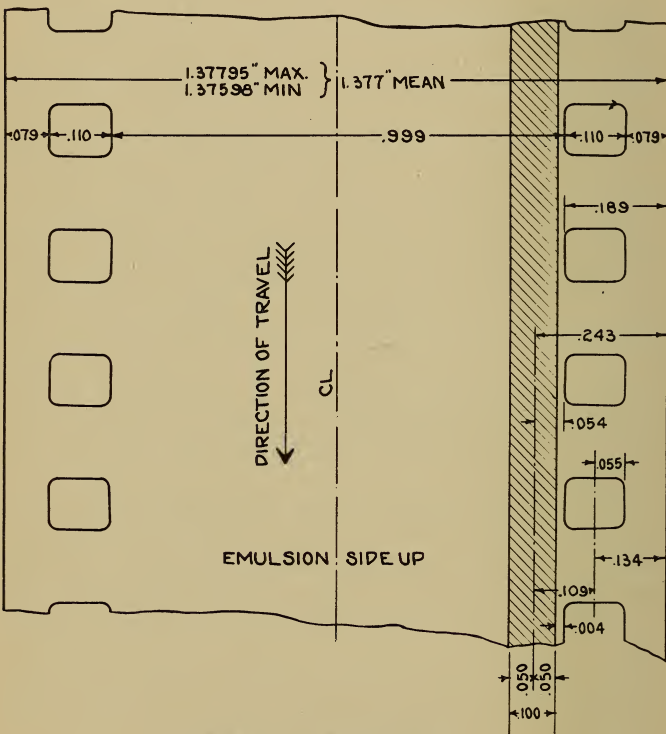
In the grid circuit of V2, anything that may happen will cause the current to deviate from normal, with the single exception of a short across R3 or R4, and the possibility of such a thing happening is so very remote that we may dismiss it as almost impossible of happening. We therefore may consider all the wiring of V2 to be OK if the tube draws plate current of normal value.

A ground between R6 and the grid of V3 in the grid circuit is all that can happen in the grid circuit of that stage without affecting the reading of the meter.

When the plate current of any tube reads high or low, the tube should be tested at once. This may be done by replacing it with a tube known to be normal, or you may test it in one of the other sockets of the 41 amplifier. If the tube is at fault, the reading will, of course, again be wrong, but if the reading on test be normal, then the trouble is not in the tube, but either in the wiring or some of the other parts of the circuit.

In case it happens that all the plate current reads high or low, the trouble will be located in the plate supply, which is a part of the 42A, or else in the 42A amplifier itself. The plate current reading on the 42 amplifier will

The following illustrations, Figures 474-478, are shown through the courtesy of the Society Motion Picture Engineers' Journal.



DIMENSION AND POSITION
OF
SOUND TRACK AREA
35 mm. COMBINED SOUND AND
PICTURE POSITIVE

Figure 474.

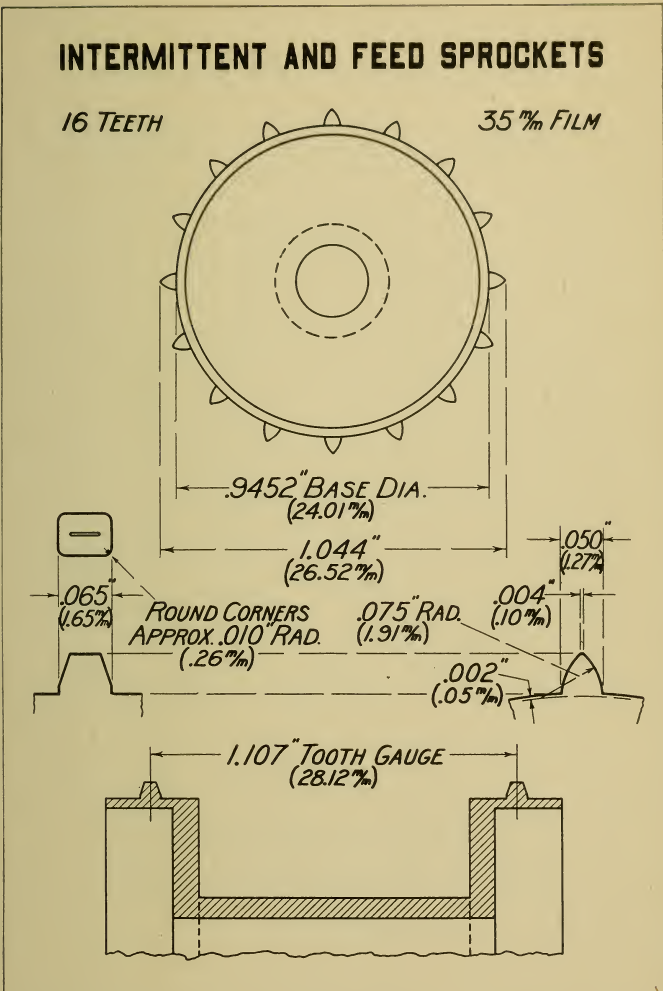

INTERMITTENT AND FEED SPROCKETS
16 TEETH
35 m/m FILM
.9452" BASE DIA.
(24.01 m/m)
1.044"
(26.52 m/m)
.050"
(1.27 m/m)
.065"
(1.65 m/m)
ROUND CORNERS
APPROX. .010" RAD.
(.26 m/m)
.075" RAD.
(1.91 m/m)
.004"
(.10 m/m)
.002"
(.05 m/m)
1.107" TOOTH GAUGE
(28.12 m/m)

Figure 475.

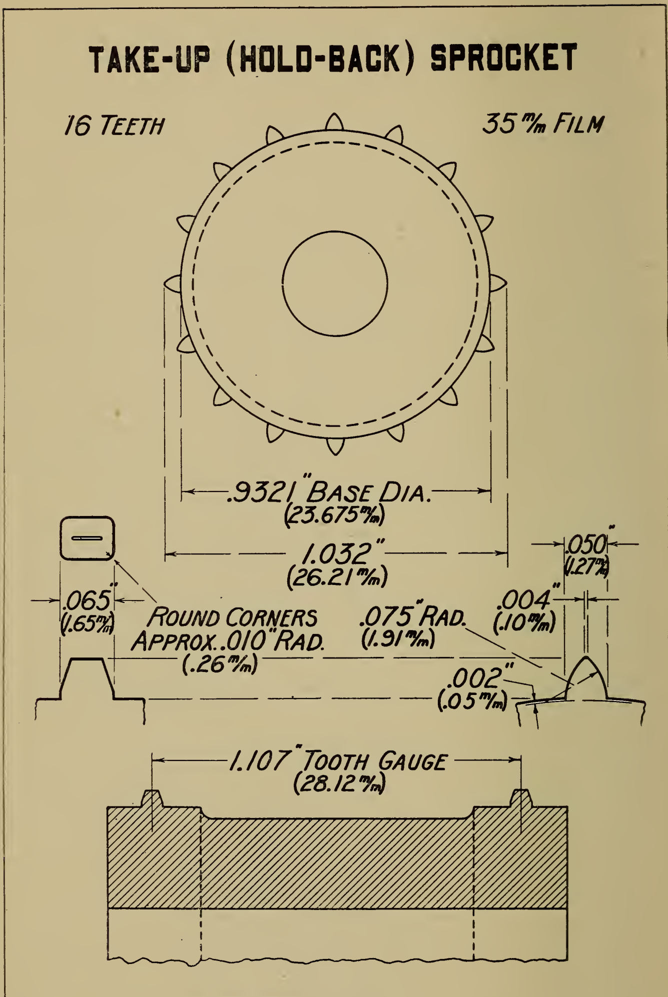

TAKE-UP (HOLD-BACK) SPROCKET
16 TEETH
35 m/m FILM
.9321" BASE DIA.
(23.675 m/m)
1.032"
(26.21 m/m)
.065"
(1.65 m/m)
ROUND CORNERS
APPROX. .010" RAD.
(.26 m/m)
.075" RAD.
(1.91 m/m)
.050"
(1.27 m/m)
.004"
(.10 m/m)
.002"
(.05 m/m)
1.107" TOOTH GAUGE
(28.12 m/m)

Figure 476.

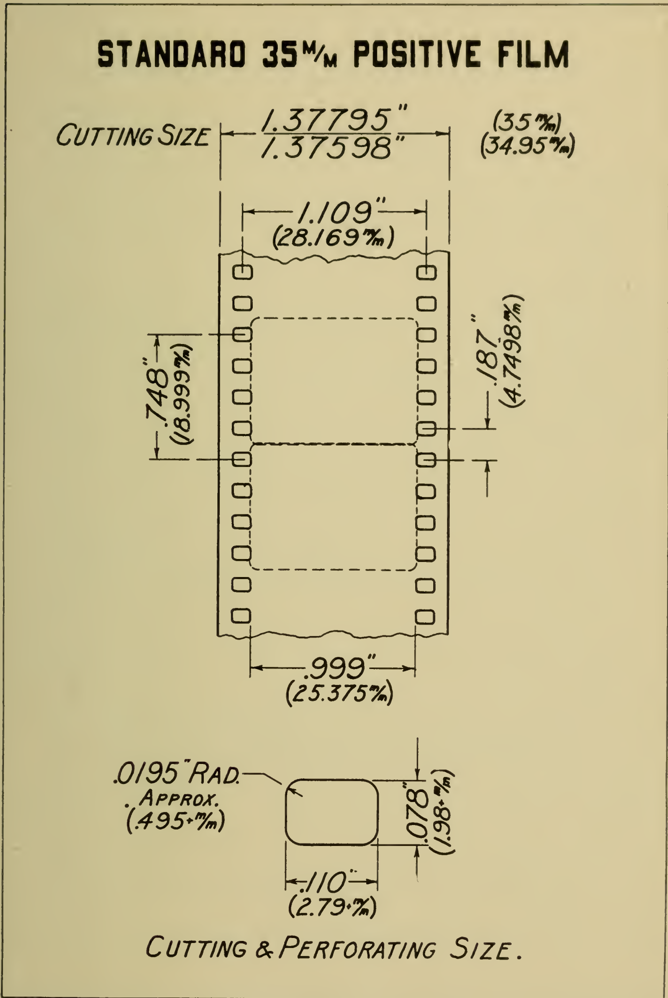
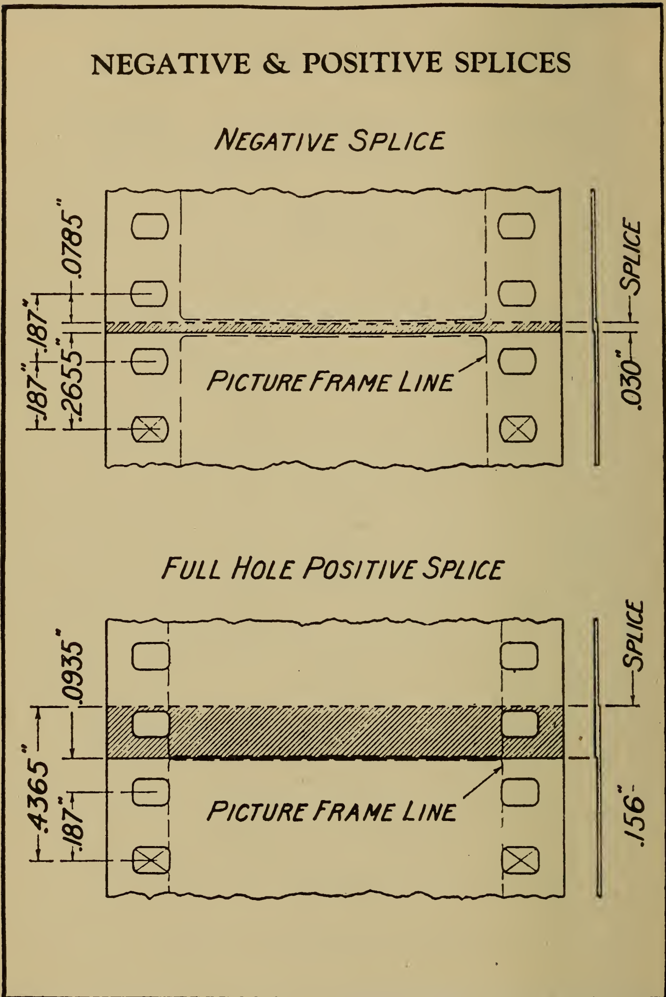

STANDARD 35 M/M POSITIVE FILM
CUTTING SIZE
1.37795"
1.37598"
(35 m/m)
(34.95 m/m)
1.109"
(28.169 m/m)
.748"
(18.999 m/m)
.187"
(4.7498 m/m)
.999"
(25.375 m/m)
.0195" RAD.
APPROX.
(.495+ m/m)
.078"
(1.98+ m/m)
.110"
(2.79+ m/m)
CUTTING & PERFORATING SIZE.

Figure 477.



NEGATIVE & POSITIVE SPLICES
NEGATIVE SPLICE
.0785"
.187"
.187"
.2655"
PICTURE FRAME LINE
SPLICE
.030"
FULL HOLE POSITIVE SPLICE
.0935"
.4365"
.187"
PICTURE FRAME LINE
SPLICE
.156"

Figure 478.

show that trouble exists here, and this must be corrected before anything is done to the 41.

Should the condenser C11 become shorted, it will be indicated on the 41 amplifier by no plate current in any of its tubes.

An open in the choke L1, or in the wiring from the choke to the three buttons used to put the meter in the circuit, results in no current at the tubes.

In event the choke L1 becomes shorted, no trouble will result unless it happens that the 42A is overloading, in which case it might cause distortion because of the drop in potential of current going to 239 tubes. Choke L1 and condenser C11 normally tend to keep the plate current voltage to the 41 steady.

Bad contacts in the switches (operated by buttons) cutting the meter into the plate circuits will cause noisy reproduction. It may cause loss of sound entirely. Any one button will only affect the circuit connected to it, of course.

The current shown by the meter is not always the current value flowing through the tube. For example: if bypass condenser C10 becomes punctured, the needle will go off the scale, because of the comparatively heavy current flow to ground. The tube, however, would be getting no current at all.

When the tubes are all right, the filament circuit likewise and the current adjusted to 270 units, the cause of a high reading in any of the stages are (a) Supply voltage above 390. (b) A ground. (c) A shorted resistance. (d) A shorted bypass condenser of any of the plate circuits. (e) A shorted stopping condenser. That is to say the condenser between the plate of V1 and the auxiliary gain control switch, or the condenser between the plate of V2 and the grid of V3. (f) An open grid circuit in any of the stages, which same will be accompanied by a hum or growl.

V1 draws a high plate current when condenser C1 is shorted. This is for the reason that it removes the grid bias by connecting the grid return directly to the filament, instead of the lower end of the biasing resistance R13 and R14.

In the event that resistance R13 becomes shorted, V2 will draw too much plate current. If R14 becomes shorted it also throws off the bias on tubes 1 and 2, but the filament current cannot be kept down to 270 when this occurs. This trouble will, therefore, be immediately indicated. It may be repaired without difficulty.

Grounded plate circuits or shorted bypass condensers in the plate circuit—a shorted condenser here actually grounds the circuit—are the only causes that will give a high meter reading and still no current be flowing through the tube. In all other cases of high current indicated by the meter it will be current flowing through the tube.

Under similar conditions—that is to say the tubes and the filament circuits being in good order—the reasons for low plate voltage are (a) Supply voltage less than 390. (b) Open plate circuit or circuits. (c) High resistance in one or more plate circuits. (d) A resistance accidentally shunted across the meter. In the case of V2, in case the grid becomes grounded, current will be below normal for the reason that there will be excessive grid bias.

When seeking trouble in the plate circuit of V3, bear in mind the fact that a portion of the circuit is included in the 42A amplifier. The input transformer in the 42 is referred to and the primary of this is the plate circuit of V3. Therefore be certain to look here and in the line from this place to the 41 for shorts, open circuits and grounds.

Distortion and noise are located in this or other amplifiers in about the same manner as was described for the photo-electric cell amplifier. Naturally anything that causes the tube to draw more or less than its normal current flow will set up distortion, unless the sound be completely killed, and at the same time may introduce noises.

Don't overlook the fact that you are dealing with about 400 volts in this and in the 42 amplifier. It may become necessary to work on the 42 amplifier with its cover off and the current on, hence the cover switch must be closed by blocking or clamping in some manner. Be very careful as to what your hands come into contact with unless you want some stiff jolts and perhaps some rather bad burns. A charged condenser, while it will not burn you, still it certainly has a terrific kick. If you are working with the power off, **be certain** to discharge the condensers with a screwdriver blade or some other handy tool before touching anything.

The filaments in the 42A amplifier are on A. C. and as no A. C. meters are, as a rule, on hand, some substitute must be found. A low voltage bulb will do very well as a test lamp. An exciting lamp is all right, or a buzzer may be used. If preferred the set may be left dead and the testing done with a battery and D. C. instruments.

The two amplifier tubes are in parallel on one winding and the rectifier tubes are in parallel on another winding of the same transformer. The filament circuits are simple and rarely give trouble. When they do it is easily located and remedied.

The contacts between the tube prongs and the springs in the sockets must be kept perfectly clean, as must also the grid and plate contacts, which are, of course, not a part of the filament circuit, but set up a lot of crackling noises when they are dirty, just as do the filament contacts.

When testing the filament circuit only, turn the switch to the filament position. This leaves the plate supply dead and there will be no high voltage in the set.

On the front of the panel are four tubes and a meter. These and the nature of the sound reproduced, will usually give us a fair idea of what has happened. Fuzzy notes of music, or as it is termed in the lingo of projection, "whiskery" music, usually is caused by a tube that has gone bad. Usually this is accompanied by loss of volume.

An overloaded tube will cause a rattling sound at the horns, but this is not likely to happen in the 42 amplifier if the tubes are in good condition, as there is hardly sufficient amplification ahead of it to cause overload, save perhaps when using a film or disc recorded at a very high level.

A leaky condenser sometimes will set up crackling noises in the horns, though this will depend largely upon the location of the condenser in the circuit, the voltage across it, etcetera.

A broken down condenser usually will cause a crackling noise which can be heard coming from the spark itself; also it gives off a peculiar burning odor which, once one is familiar with it, cannot be mistaken. By removing the amplifier cover and blocking the cover switch in closed position, one may sometimes see smoke coming from the defective condenser. In case no smoke or spark can be seen, cut out one bank of condensers and try the amplifier to see if it now is all right. Then try it with the other bank cut out.

Once you have determined which bank the trouble is in, you can then cut out each individual condenser until the faulty one is found. To get the show going again as soon as possible, after ascertaining which bank the faulty condenser is in, leave the entire bank of condensers out of circuit and continue with the show, making the repair after the performance has ended. You then may test the condensers with battery and phones, or in some other manner if you desire.

Any tube the plate of which is decidedly red or yellow has abnormal current flowing through it. Normally the plates of the rectifier tubes will be dark, the plates of the amplifier tubes will be cherry red. They may only be seen when the tube is shaded from all outside light. Should any tube get much hotter than this, there is trouble which must be found and rectified.

If the grid and plate of one of the amplifier tubes should touch each other, it will cause the plates of both the tubes to overheat and the meter to go off the scale. This is because of the heavy current flow due to the fact that the grids have gone positive. Of course under this condition no sound will come through; also the plates of the rectifier tubes will be overheated. Removing the shorted tube from its socket removes the fault. The meter will then read between 35 and 46, which is about right with one of the tubes out.

Should the plate and filament of an amplifier tube become shorted it short-circuits the plate supply. The amplifier tubes remain cool but the rectifiers are burning up. The meter will go off scale.

When the grid and filament became shorted the tubes will draw very heavy current, though nothing like that caused by a shorted plate and filament. The meter will probably go off scale again.

A short in the wiring of the grid and plate circuits will show up the same as a short from the grid to the plate inside the tube, but removing a tube does not restore things to normal. Removing both tubes brings the meter to about 5 mils. This is the current that is flowing through the short, through half of the input transformer, then through the 48,000 ohms resistance and thence to ground.

A ground to the plate circuit between the meter and the tubes will cause the meter to go off scale, and it will remain that way, even with both amplifier tubes removed. The plates of the two rectifier tubes will be burning up.

A ground on the supply side of the meter does not give a reading on the meter. Such a fault may be suspected when the rectifier plates become extremely overheated and the meter reads zero, although the ground is due to a shorted condenser, a small current value will often show on the meter. It may be anything from 0 to 20 mils. A shorted condenser is, by the way, almost always the cause of such a ground.

A grounded filament circuit in the amplifier shorts the bias resistance, in consequence of which the plate current goes up again.

A ground in the rectifier filament circuit shorts the plate supply. The rectifier plates will be burning up, no current showing on the meter and the amplifier tubes remaining cool. The effect is the same as with a punctured filter condenser. The filaments are the positive source of the high voltage and are directly connected to the first bank of the filter condensers.

A shorted filter choke, or an open in the wiring to the filter condensers, providing the path from the rectifier filaments to the output transformer is unbroken, and that the path from the center of the high voltage transformer to the ground also is continuous, will cause no trouble, as this amplifier can be supplied with almost unfiltered, rectified current, and yet not produce sufficient hum to be objectionable. Also there will be no hum produced in the 41 amplifier by reason of poor filtering in the 42, by reason of the fact that the 41 itself has an elaborate filtering system.

Opens in the grid circuits set up hum and high plate current.

Opens in the plate circuits obviously stop the current flow to the tube, or to the tubes, as the case may be.

No plate current flows when the bias resistance becomes open circuited, since it really is a part of the plate circuit. It forms the path from the filaments back to negative B.

Troubles which may occur in the wiring of the 42 amplifier is quite easily repaired, but when some of the parts themselves go bad it becomes quite a difficult problem. Other parts cannot easily be substituted in this amplifier. Not only must any replacement have very nearly the same values of the part replaced, but also they must carry a fairly heavy current—60 mils. For proper safety allowance they should be capable of carrying 100 mils at least.

It is quite simple to find a substitute for the 48,000 ohm resistance connected between the input transformer and the negative B, which, by the way, is extremely unlikely to develop trouble. It may be replaced by resistance carrying practically no current, and if no such resistance is at hand, in ninety-nine cases out of every hundred it can be shorted out without any great harm resulting.

Should the bias resistance become open circuited it can be replaced by two 10-watt, 110-volt lamps wired in parallel, though this gives just a trifle too much bias. One 25-watt lamp might be used, but this would not be quite as effective, as the resistance would be about 100 ohms too low, which would cause the plate current to be quite heavy.

Either of the chokes can be cut out, one located next the meter being of least importance. They may be replaced, in emergency, by any choke capable of carrying 60 mils and not having too high a D. C. resistance. Of course, however, if the choke has less inductance than the one it replaces it will not be quite so effective. If it should have too much inductance then the D. C. resistance will also be high, which will reduce the voltage at the plates. This will reduce amplification slightly and may cause the amplifier to overload on loud reproduction.

Any of the condensers may be left out, with the exception of the half mike used across the biasing resistance. There is only a low voltage across this condenser and it will probably never give any trouble. If it should, however, it may be temporarily replaced by another which is at least as large.

NOTE.—In event some acceptable substitute be used for replacement, always remember it is only a temporary makeshift. Secure a proper duplicate replacement part and install it as soon as possible.

Not much can be done in case any of the transformers go bad, with one possible exception, namely in the case of a grounded transformer. This can possibly be remedied by insulating the transformer from the panel and removing the transformer ground wire, if one there be.

Little need be said concerning the 43A amplifier, as its hook-up is very like that of the 42A, the chief difference being in the values of the voltages and currents. All the parts are built to withstand the higher voltages. Actual troubles and their remedying are the same as those set forth in dealing with the 42 amplifier.

In case the 43 amplifier goes dead, the leads may be removed from the output terminals of the 42 amplifier, and the two others attached in their place and run up to the 200A panel. The leads going from the 43 to the 200A should be removed, of course.

When the equipment consists of two forty-threes, and one of them goes dead, remove the leads from the dead 43 and put the leads from the remaining 43 on the 500 ohm output terminals of the 42.

Many believe the 41 or the 42 amplifier may be cut out, but this is not true. Should the 42 go dead the plate supply for the 41 is gone also, even if a source of plate voltage were at hand, the power output of the 41 is so limited that it would be nearly useless, insofar as putting signals directly into the horns be concerned.

The 42 or the 42 and a 43 cannot be used alone because that would leave only one, or at most two stages of amplification, and that is far too little. Most of the amplification is on the system occurring in the 41.

In cutting out an amplifier there also is the problem of impedances at the input and the output of the devices. The difference of the impedance of the output of the fader and the input to the 42 is so great that almost no signal could be transferred from one to the other.

The results would be very similar were an attempt made to cut out the 42 amplifier. The output impedance of the 41 being about 15,000 to 20,000 ohms and the input impedance to the 200A panel about 500 ohms. Again, only a very small portion of the signal would be transferred from one to the other.

From what has been said it will be seen that the only amplifier that may be cut out with fairly satisfactory results, as the equipment now is made, is the 43A.

In the output panel it frequently happens that one of the switch arms is left touching two of the contact studs. This may by some be considered as unimportant. However, it certainly does injure the quality of reproduction, hence it should be carefully guarded against.

There are several places on this panel where a ground can occur, and such ground will usually kill all sound, though an open in most of these places will only kill the sound in one horn. An open in the autotransformer, or between this point and the output of the last stage will cause all sound to stop. The separate circuits involved may be tested at the panel in the rear, using a phone.

A short in any of the speech circuits going to the horns will kill everything. The circuit at fault may be located by testing the individual horns, one at a time. All horns will give sound except the one attached to the faulty circuit.

Trouble occurring in the circuits going to the fields of the units are the same as would occur to any line carrying D. C. They therefore should need little discussion. The trouble probably most frequently encountered would be low H batteries and blown fuses in the B box. Occasionally, in vaudeville theatres where the circuits to the horns are disconnected and plugged in again after acts, some careless one will neglect to re-connect the circuit by "plugging in." No sound from one or more of the horns will, of course, be the result, which is a matter up to the Manager or Stage Manager to deal with—and drastically, since the fault is utterly without any possible excuse.

When the unit itself goes bad, there is nothing else to do except install a new one. A dead unit is almost always caused by a burned-out voice coil, which the projectionist certainly would have a hard time making the repair; also such repair is strictly against ERPI orders. Do not attempt it.

There are a few other troubles with which units are afflicted from time to time, such as rattling and a unit which is quite all right except on a certain portion of the frequency range. Again, in such cases the only thing to be done is install a new unit.