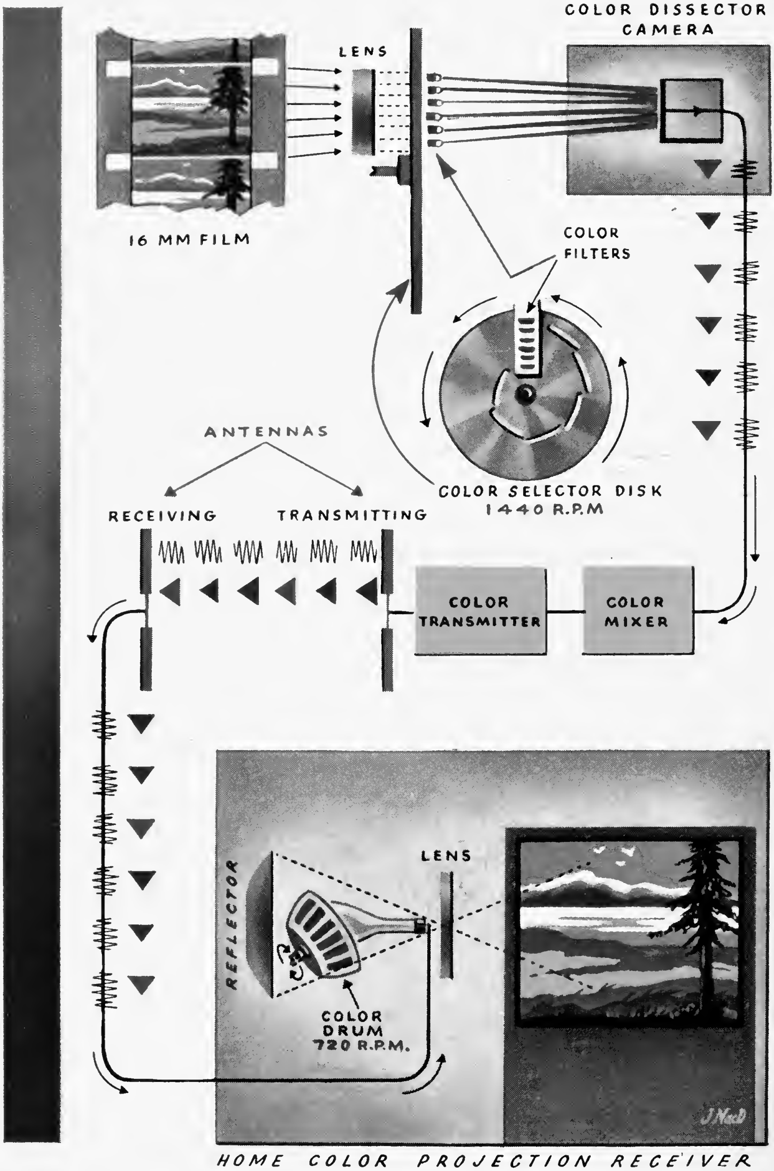
TELECASTING and COLOR

TELECASTING *and* COLOR

also by KINGDON S. TYLER

MODERN RADIO

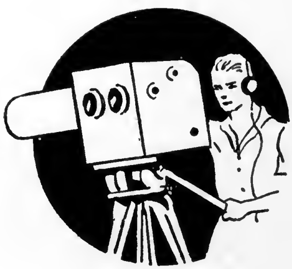


C.B.S. COLOR SYSTEM FOR FILM

TELECASTING and COLOR

by Kingdon S. Tyler

ILLUSTRATED WITH DRAWINGS BY JAMES MACDONALD
AND WITH PHOTOGRAPHS



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KINGDON S. TYLER

New York City
September, 1946

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TELECASTING *and* COLOR

Chapter One

TELEVISION BACKGROUND

MANY millions of man hours and dollars have been spent developing television over a period of 20 years or more. The engineers in the laboratories have put forth numerous ideas to improve television picture quality and to eliminate transmission problems. These ideas have been tested, the impractical ones have been weeded out and the better ones improved upon. Today, large screen television pictures of excellent quality can be transmitted and received. Experimentally, colored television pictures have been transmitted and received with very good results. These pictures are comparable to colored motion pictures. Before long this process should be perfected so that the public may purchase full color receivers.

The basic principle for transmitting television pictures was thought of years before electronic transmission systems were developed. That is, a device to break a picture down into small parts which could be reassembled was invented many years ago. The first device was a rotating disc which scanned the picture. It was called the Nipkow disc and patents were granted for this machine in 1889. Years later, the transmission system was developed so this device could be used to dissect and reproduce a picture. Successful experiments using a mechanical scanning system for transmitting pictures were completed in 1927 by the General Electric Company.

Some of the first television pictures were produced by the use of a rotating disc which contained a series of small holes. The disc mechanically broke a picture down into small parts. These small parts were transformed into electrical impulses and sent to the receiver. A similar rotating disc was used at the receiver to reassemble the picture. This process was known as mechanical scanning. It proved that pictures could be transmitted electrically, but the picture quality was poor.

If you look at a newspaper picture with a strong magnifying glass you will discover the picture contains many thousands of tiny dots in varying degrees of gray. Each one of these dots represents a tiny part of the entire picture. If in reproducing this picture the number of dots were reduced (even though the size of the ones used might be increased), the picture would become coarse and lack fine detail. If you think of these dots as small parts of a picture it is fairly easy to visualize what occurred in early television. The mechanical method of dissecting a picture was limited by the number of picture elements (the small dots or parts of a picture) it could transmit. Because only a limited number of picture elements could be transmitted, the quality of the transmitted picture was very poor.

A big technical advance in television came when electronic picture tubes were developed. These are capable of electrically dissecting and reassembling a picture. Two vacuum tubes are used—one for dissecting or transmitting the picture and one for reassembling or receiving the picture. These tubes operate by controlling a tiny stream of electrons which bombard a screen on the inside of a vacuum tube. Through a lens system the picture to be transmitted is projected onto a screen inside the transmitting tube. A tiny stream of electrons, generated inside the tube, is played back and forth across the screen of the transmitting tube to dissect the picture. This stream of electrons causes the picture on the screen inside the tube to be transformed into electrical impulses. These electrical impulses are then transmitted to the receiving tube where the picture is reassembled by another tiny stream of electrons which play back and forth across the screen of the receiving tube. Through the development of these tubes, television pictures can now be transmitted and received purely by electrical means. This electrical method of transmitting enables the engineers to transmit pictures containing far more detail than was possible by the earlier mechanical method. As new electronic television tubes have been developed to a higher degree, better pictures have been reproduced. The fundamental operating principle of these tubes was invented in 1907. At this time, however, the electronic tube had not been invented, so the device had to wait for the development of the electronic tube. In 1929 television images were produced by applying this principle to the electronic tube.

Television pictures are transmitted line by line. If you were to start at the top of a photograph and work toward the bottom, cutting the picture into long thin strips, you would be dissecting a picture in much the same way as the television electronic tube does. That is, the television camera dissects the picture line by line, starting at the top and working toward the bottom. The details of this process are explained more fully later on.

The number of lines or strips the picture is dissected into by the camera determines the amount of detail the picture will contain when it is reassembled by the television receiver. This is true because each line represents a certain number of picture parts and the amount of the detail increases with the number of individual parts transmitted.

Early electronic television pictures were produced by breaking the pictures down into one or two hundred lines. Technical difficulties limited the number of lines that a picture could be divided into for transmission purposes, so these earlier pictures lacked considerable detail. They were not distinct enough for general use, as the public had been educated to the high standards existing in motion pictures. So television stayed in the laboratory until more lines could be produced per picture.

By 1939 pictures containing 441 lines could be transmitted. When this point was reached, manufacturers felt they could produce pictures of a quality that would be accepted by the public. A 441 line picture is of a quality comparable to 8 or 16 millimeter home movies.

Studios were built, transmitters were put into operation and television receivers were sold. Television programs of various types were produced. Musical comedies, dramas, news broadcasts, hockey games, baseball games, fights and many other types of entertainment were telecast.

World War II interrupted television's commercial development, as all available man power and equipment had to be applied to the war effort. It happened at a time when television was just beginning to spread its wings and when public interest in television was growing daily. This was a big setback for it gave the "Doubting Thomases" a chance to say "I told you so."

The opposition to television claimed the receiver pictures were too small and indistinct. They said the cost of receivers was so high that only a limited number of people could afford to purchase them. They pointed to the fact that television transmitters could only send their signal 40 or 50 miles so that a great many people could not receive programs. The opposition claimed programs could not be sent from city to city as special costly transmission lines were necessary for this. Their claims were true in part, and many people felt that television would be a colossal failure.

During the war television and radio engineers worked day and night producing special radio and electronic equipment for the Army and Navy. They developed many different types of radio and radar equipment. New techniques were devised for transmitting voice, code and indicating signals. The engineers produced small lightweight radio transmitting units which were capable of sending their radio signals greater distances than most pre-war engineers had believed possible. They not only developed the use of radar for the detection of planes and ships, but they found new ways of using its fundamental operating principle. Radar functions by sending out short radio signals which travel in a straight line and are reflected by any hard surface. Part of the wave is reflected back toward the sending station. The signal, which returns like an echo, is picked up by an antenna. By the use of an electronic oscilloscope tube, the time difference between the transmitted and the received signal can be measured. As the speed of radio waves is known (186,000 miles a second) the distance between the transmitting point and the object the wave strikes can be measured. This basic radar principle is used in many ways to detect and locate unseen objects. Electronic altimeters were developed which gave the airplane pilot his exact height aboveground to within a few feet. This device is known as the Absolute Altimeter. Electronic bomb sights were built which enabled pilots to bomb their targets through clouds or in the dead of night. The engineers, in creating these devices and many others, had surpassed their wildest pre-war dreams.

While these electronic war devices were being developed, television was in a stagnant state. But the very things which retarded it are responsible for its greatest advancements now, because the knowledge gained by the development of this special wartime electronic equipment was later applied to television.

Many of the difficult problems facing pre-war television have been overcome. While it was possible to produce large television pictures before the war, the 441 line picture did not contain sufficient detail. This made the picture coarse when it was enlarged. Today, experimentally, 1,000 line pictures can be produced which retain sufficient detail when enlarged to provide excellent quality.

Another important improvement in television is the relay transmitter. This system of transmission was developed to a high degree during the war. Relay transmitters pick up a program and re-transmit it from one city to another. If a television program is to be sent from New York to Chicago by relay transmitters, this is the way it is done. A program sent out by the new Columbia Broadcasting System colored television transmitter on the 71st floor of the Chrysler Building will be picked up by a television receiver located forty miles away in the general direction of Chicago. The receiver feeds the program to a small, low-powered television transmitter installed here. This transmitter will have a special, highly directive antenna system which can send television signals out in the form of a narrow beam. While the transmitter itself is low-powered, by concentrating all the energy into a narrow beam, a powerful signal can be sent in a single direction. If this beam were visible it would look like the beam of a searchlight. The antenna system will direct the beam toward Chicago. In this way the program can be received and re-transmitted toward Chicago. This is known as a relay transmitter.

By using several of these relay transmitters in a line stretching from New York to Chicago the program can be transmitted between the two points, although it may have to be received and re-transmitted twenty-five or thirty times before it reaches Chicago.

The system was used even before the war to send programs originating in New York City to Schenectady, but this type of transmitter was greatly improved during the war and relay stations are being installed at the present time to carry programs from city to city.

There is a second method of transmission which utilizes a special line called a coaxial line for transmitting programs. It is necessary to send television programs over a special type of line or conductor because of the nature of the energy transmitted. While sound can be changed into varying electrical energy and sent over telephone lines quite easily, much faster and greater variation of current is necessary to transmit television pictures. This varying current which represents the television picture radiates its energy so rapidly when it is sent over ordinary telephone lines that a great deal of energy is lost by this radiation. It is therefore not practical to transmit television pictures over ordinary telephone lines, and engineers have developed the special line for transmitting pictures. The coaxial line has already been installed between some of our larger cities. The cost of producing, installing and maintaining this type of transmission line, originally very high, is now low enough so that the transmission line is practical for television transmission.

Camera picture tubes have now been developed which are more sensitive to light than any tubes previously produced. A scene around a dining table, lighted only by candles, can be transmitted with this new tube. These more sensitive tubes will reduce the problem of high intensity lighting now necessary on the television stage.

One of the greatest improvements in present day television is the combined transmission of picture and sound. In the older system, which is still in general use, sound and picture must be kept separate from the time they leave the studio until both are reproduced by the receiver. Besides separate transmitters for sound and picture, separate transmitting antennas are needed. A short time ago a new experimental transmitter, capable of sending sound and picture simultaneously, was put into operation. The new system requires only one transmitter and one antenna system. Sound and picture are mixed together in the studio and sent over a single line to the transmitting station. The transmitter amplifies this electrical signal which contains both picture and sound, and radiates the energy from a single antenna system.

The new transmitter produces pictures of greater clarity than any commercial transmitters used before the war. It is also capable of transmitting full-color television pictures.

Television is no longer a laboratory experiment. It is ready to entertain and educate John Q. Public.

Chapter Two

PROGRAM RESEARCH

WHILE tremendous technical strides have been made in telecasting, little has been done to develop good programs to which the telecasters can be sure the public will react favorably. One of the reasons television programs have not reached a high standard is that years were spent developing technical equipment and very little thought was given to programming. It was only a short time after the first regular programs were produced that it became quite evident that the programs were not up to radio-broadcasting standards or the high standards maintained in motion pictures.

When radio broadcasting started, no standards existed for this type of entertainment so the poor quality of the early programs was not so evident. Radio developed in the early days by trial-and-error methods. Programs were produced and put on the air and the broadcasters sat back and waited for the public reaction. If it was unfavorable, a new type of program would be tried. This was a very slow and costly process, so radio set out to develop a scientific means of measuring public reaction. Today broadcasters know what type of program will go over. They know the best time of day to put on a certain type of program. They know the sort of people it will reach. They know the potential buying power of the listeners and many other important facts related to programming.

The public is the final judge, so the reactions of the public are constantly checked by scientific means. The radio industry uses many different methods to check these reactions. Telephone calls are made to hundreds of homes. At times contests are developed so that people will write in and give their reactions. Often the public is invited to a studio and their reactions are checked on the spot after they have listened to a program. The latest device for checking reactions is a mechanical and electrical machine which records the reaction of the listeners in a studio. This machine indicates the likes and dislikes of all the listeners for each spoken line in the program. All these reactions are automatically indicated on paper. These various checks help the broadcasting companies in selecting program material, in knowing the proper time to put it on the air, and in deciding for what field of advertising it is best suited.

The Columbia Broadcasting System was one of the first to realize that these devices could be applied to television and that if this were done it would save years in bringing television programs up to a high standard. Of course, all the methods of checking public reaction to broadcasts could not be applied to television. Also, new methods of checking reactions had to be developed. This research work covers many phases of television besides the program material, including stage operation and equipment design. It covers the public reaction to certain camera shots, to the way the stage is lighted, to the size of the picture on the receiving screen, to the distance a person must sit from the receiving screen for best results. These television tests were developed by the Columbia Broadcasting System. The first series of tests were conducted simply, but afforded a great deal of valuable information when they were tabulated and analyzed.

At first, invitations were given over the air for people to visit a broadcasting studio and see a television show on a standard home receiver. They were informed that they were to be used as guinea pigs for a series of television tests. By questionnaires, the general background of each person was established. Without this, their reactions would have been of little value. For example, if one person lived a quiet home life and only rarely sought outside entertainment, his likes and dislikes would not necessarily be typical of the general public. The reactions of a person who enjoyed radios, movies and stage shows were of more value. The questionnaire also indicated the daily habits of each person. This was important, as domestic or business interests affect the type of programs people enjoy.

These questionnaires were filled out prior to the viewers seeing the television program. During certain phases of the program the entertainment was interrupted and various people were questioned as to whether that section of the program was interesting or humorous. They were also questioned as to whether they thought the picture lacked detail or was not brilliant enough. They were asked if they suffered from eye strain or noticed any flicker. Their comments were tabulated so they could be checked against the questionnaires they had previously filled out. Naturally, to accomplish anything with tests of this type a great number had to be run. While the individual groups were small, numerous tests showed the equivalent of two hundred or more reactions.

Later on, instantaneous reactions will probably be checked by the use of the program-analyzing machine. Two machines of this type have been developed, one which records the reactions of 20 people simultaneously and another which records reactions of a hundred people simultaneously. The smaller machine consists of a single recording device with 20 indicating pens. These pens rest on a sheet of paper which is constantly in motion so that 20 straight lines are normally drawn on the paper when no reactions are recorded. Each person in the audience is equipped with 2 push buttons which are electrically wired to the machine. One push button is painted green and the other red. The viewer holds one button in his right hand and the other in his left. By pressing the green button he records his approval of that part of the program. By pressing the red, he shows disapproval. The indicators in the machine automatically record these reactions. As the paper moves at a constant speed the time can be checked against the program log so that the research men can tell what part of the program the reactions apply to. The machine which is used for an audience of a hundred people has two recording machines, each recording machine equipped with a single indicator. One machine records all the approvals and the other machine the disapprovals. The recording pen swings from left to right across the paper. If 50 people disapproved, the pen on the machine registering disapproval would swing halfway across the paper. If 25 people approved, the pen on the approval machine would swing one quarter of the distance across the paper. Analysis of this would indicate that 50 people disapproved, 25 approved and 25 had no reaction. If the program is produced from motion picture film, which is sometimes the case, it is quite easy to reproduce the program and check the reactions. By doing this, the parts of the program that have had bad reactions from the viewers can be eliminated and more interesting parts can replace these eliminated sections.

Naturally, a great deal of experimenting is being done on the television stage. Trick shots are tried out, odd lighting effects, various ways of shifting from one scene to another by overlapping and fading. Other effects such as moving the camera at certain angles while the picture is being taken have been experimented with. This research has shown which of these trick devices for creating interest are acceptable. Various types of programs are also experimented with —plays are produced, amateur boxing bouts, bedtime stories, audience-participation shows. These entertainments are carefully selected but the research department has proved that some forms of entertainment will not be popular. It is known that television will be a new medium of entertainment, that it will not be like the movies, as most people believe. Few people will care to sit in their homes and view an hour or an hour-and-a-half continuous show. The public reacts differently when viewing a picture at home. Interruptions by visitors, telephone calls and conversations interfere with long continuous programs. Research men do not believe that television is similar to broadcasting either. Most people show little interest when they see a program being produced by people reading scripts, so television cannot hope to borrow much from broadcasting entertainment. One of the main interests in television today seems to be sporting events. This may change, however, when the studio form of entertainment has been developed to a higher degree.

Research work has also been applied to colored television. Tests were conducted to determine whether the public preferred present-day colored television to black and white television. These tests included the public reaction to the size of the receiving screen. Checks were made on how much the public would pay for a colored television receiver. This was done by showing colored television to several groups of typical owners of black and white television sets. Approximately 90 people were tested. Results indicated that the viewers would be willing to pay 34 per cent more for a color receiver with an 8″ x 10″ screen than for a black and white one of similar size. They would be willing to pay 28 per cent more to receive colored pictures on a projection type receiver with a 16″ x 22″ screen than for black and white. In a direct comparison test, only 12 per cent of the people were satisfied with black and white pictures after comparing them with the latest color system.

Tests were also made to determine whether the viewers preferred a 16″ x 22″ picture in black and white, or an 8″ x 10″ picture in color. Only one out of four people preferred the larger black and white picture to the new color system. This group was also questioned as to whether they thought it would be better to spend money developing colored picture transmission or on improving the quality of programs in black and white. Six out of seven people agreed it was better at this time to spend money to develop colored television so that the public could purchase receivers. This reaction was checked by using a list of check words which might be applied to either colored television or black and white.

By using these reaction tests, a large company can guide its planning of future television programs. As time goes on, more elaborate and more detailed tests will be made. By using this research information, preliminary data on colored television has been gathered and the production and stage operations of black and white television have already been changed. The real value of these tests will probably not be realized for another year or so, because—until more receivers are sold and more people become acquainted with telecasting—large stage productions will not be scheduled. In other words, large sums of money will not be expended for high quality program productions until more revenue is coming in to the broadcasting companies.

However, this research work can aid in plans for better equipment and program material. When television is in a position to expand, a great many faulty ideas, which would only retard its progress, will have been eliminated. Therefore, we can expect television progress from a program point of view to be much more rapid than in radio broadcasting even though it is far more complicated.

Chapter Three

THE TELEVISION STAGE

THE general belief of the public is that a television stage operates in the same manner as a motion picture studio, and that the same type of equipment is used to produce television shows. This is only partially true. Cameras, lights, microphones, props, and operating personnel are necessary to both. Television, however, requires a more flexible stage, a great deal more technical equipment and a much larger operating personnel. In motion picture work a lot of short scenes can be taken at different times and then pieced together afterwards. Also, a scene can be shot several times until it is letter-perfect. Even after a picture is complete it is still possible to cut scenes and retake parts if they are found to be unsatisfactory.

Television, on the other hand, is a one-shot proposition when live talent shows are put on. A show must be rehearsed until it is letter-perfect so that when it goes on the air there are not any slips or bad scenes. If three or four scenes are used, then all of these scenes must be set up on the stage at the same time. The control room takes care of shifting scenes by camera switching. This requires a great deal of precision and accuracy on the part of the operating personnel and the actors.

Television shows can be and are produced from motion picture film, which allows more latitude, but it is believed by many that these shows will not be popular. The transcribed or canned type of radio show has never been as popular as live talent shows and this will probably also be true in television. The present practice is to produce some shows directly and others from film. It will be necessary to do this for some time as most broadcasting companies only have one or two television studios and these are tied up during the day with rehearsals for evening shows. Stations are now increasing their television hours on the air, but their studio capacity for live shows cannot keep pace with the demand.

Television studios at the present time are all sizes and shapes. The larger studios afford more flexibility as two, three or four scenes can be set up at one time. This is the type we will consider as we believe the tendency will be toward larger studios.

One of the largest television studios operating today is 56 x 83 feet with a 30-foot ceiling. The lighting is so ar-

Courtesy of C.B.S.

TELEVISION STAGE

ranged that three sets or stages can be set up at one time. This studio has been experimenting for some time with lighting, as this is one of the main problems today. The lighting arrangement must be as flexible as possible to permit different lighting setups for various types of shows.

One of the latest lighting devices used in this studio is a tubular steel scaffolding. The various tubular parts are clamped together and can easily be removed or loosened with a hand wrench. This enables new arrangements whenever necessary. This scaffolding framework hangs over the entire stage area. It also extends in front and on each side of the acting area.

Catwalks around the framework can be arranged at almost any location. By changing these tubular parts, the framework can be extended, raised or lowered to any desired position. Spotlights, floodlights, special arc lights and high intensity incandescents can be clamped to this framework to produce various lighting effects. It provides a means of arranging the lights at any location or elevation around or over the entire acting area.

As this framework is suspended from the ceiling, it allows free movement of cameras, microphone booms and other stage equipment. It also leaves the stage clear for the arrangement of various sets. The men (grips) who handle the lights use the catwalks to adjust various lights or to move them to new locations.

In addition to this lighting framework, small mobile frames are used on the stage for spots and floodlights when it is desirable to have some of the light directed from a low angle. These units can be pushed around the stage and set at various angles to produce highlights, shadows and other lighting effects.

At the present time, television requires considerably more light than is ordinarily used in motion picture work, because the television camera is not as sensitive to light as the ordinary motion picture camera. In order to reproduce a picture, more light is required on the object to be televised. However, more sensitive camera picture tubes have been developed which will reduce the amount of light required.

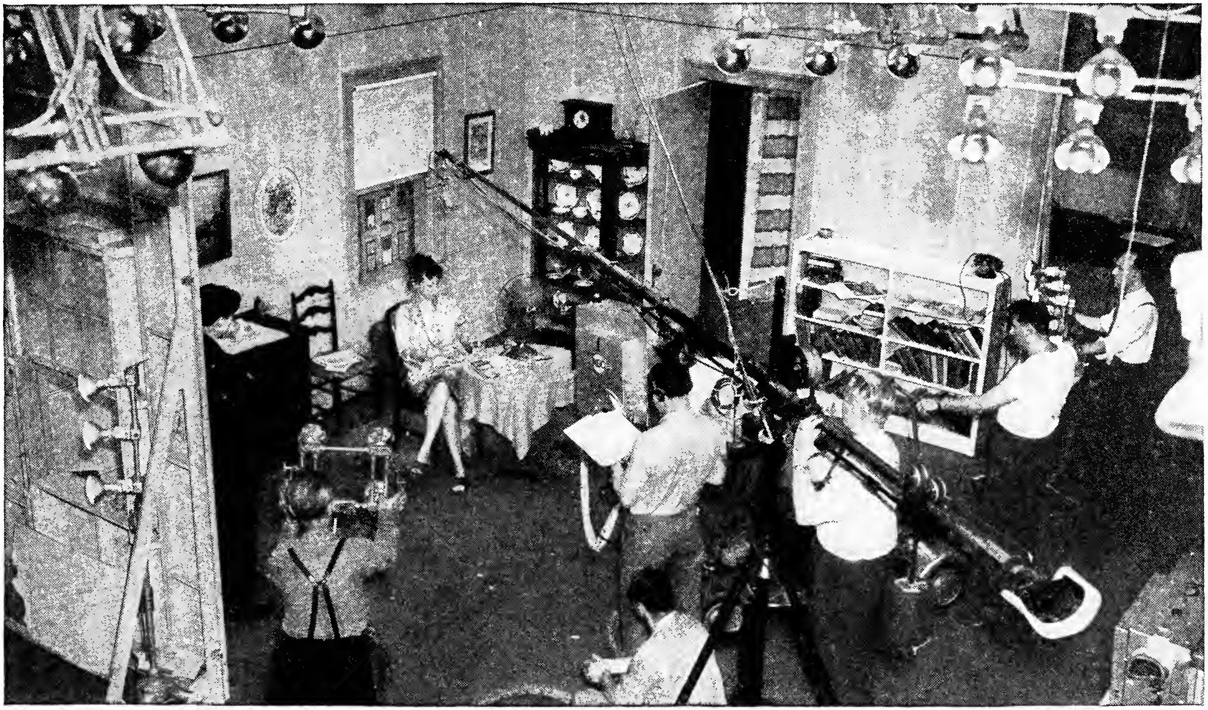
At present, an average scene on the television stage requires approximately 500 foot candles of light, foot candle being the candle power per square foot of area. If you have 10 foot candles of light over a given area, then you have 10 candle power of light falling on each square of that area.

The intensity of light varies over the entire stage. The whole area is usually flooded with general lighting. Then higher intensity floods are used to brighten certain areas. Back lighting is used to create the illusion of depth. This is accomplished by using a high intensity light directed from the back part of the stage. The light is usually placed on one side so it will not shine directly into the camera. It can be concealed by the stage scenery. This trick which creates the illusion of roundness and depth in a picture has been used by still picture cameramen for years. Still and motion picture cameramen have developed trick lighting effects to a high degree and it is believed that a good many of these effects can be used for television.

Lighting a set is an art and each scene requires a different type of lighting. Lighting does for a picture what sound effects do for radio. It creates moods and illusions and can be the means of adding realism to a picture.

The television studio is really a large acting area where various stage sets can be erected to reproduce the background for almost any type of program. The most modern type consists of a large studio where two or three stage sets can be arranged for different scenes. For a single program at the present time, usually only one set is used, so a large studio can arrange three sets at one time, this being enough to take care of possibly one half-hour show and two 15-minute programs.

Usually, at one side or at the end of the studio is the television control room. This room houses the technical equipment for picture and sound transmission. The control room is separated from the studio by a large soundproof glass window. To make the window soundproof, double glass windows are used. There is an air space of approximately 4″ between the two panes of glass which makes the window soundproof. Usually near the control room is a projection room. This room is similar to a standard motion picture projection room used in theaters. It usually contains two or three motion picture projectors. These machines make it



Courtesy of N.B.C.

N.B.C. TELEVISION STUDIO PROGRAM "LIGHTS OUT" SHOWING STUDIO EQUIPMENT possible for part of the television program to be taken from motion picture film. The picture is projected through a small opening in the wall of the projection room. On the other side of this wall is a special type of television camera housed in a box. The picture is projected into this camera which transforms the picture into an electrical signal in the same manner as a studio television camera. Quite often the camera is mounted on tracks so that it can be moved along the wall in front of each projection machine. In this way one camera can be used for two or three projection machines as only one machine operates at a time. This enables the projection man to load one machine with film while the other is in operation.

Some of the most modern studios have a carpenter shop located near the stage. In this shop various props are built, such as sections of a ship or plane, wooden gates to imitate elaborate iron gates, windows, special tables, fire hydrants and many other objects. This shop also constructs wood frames for the stage sets. Material is stretched over these frames and they are painted by a scenic artist to form the backdrop for various scenes.

As an example, if a living room scene is called for the carpenter shop would supply painted flats to form the wall of the room. It might also construct an imitation brick fireplace, bookshelves and other articles used in a living room.

At the present time most large companies are drawing up plans for even more elaborate television studios. The Austin

Company, a construction engineering firm, has designed a studio with a revolving stage. The plans are that four sets can be arranged on this revolving stage. The stage can be turned around so that the scene being taken will always face the control room. The audience would sit above the control room and thus have a direct view of each scene as it is being taken.

Mr. C. R. Jacobs of the Columbia Broadcasting System, well known radio studio designer, has also developed plans for new television studios to be constructed in Hollywood. The control rooms are so designed that the operating personnel can view all areas of the television stage. It is possible to set up as many as five different sets at one time. New devices are being designed for more flexible lighting. The studios will be equipped with storage space for scenery and props. Near the stage will be a modern carpenter shop. The studios will have special acoustical treatment to give more faithful sound reproduction, and will be built so that the television audience can watch the program and the stage-operating personnel.

Plans have been announced for a new television project in the heart of New York City. Instead of it being a Radio City it will be a Tele-City. This project will cost around 60 million dollars. It will have many large studios which can be used for either motion pictures or television. At the present time, no details have been published regarding this project.

While there are relatively few television studios with modern equipment in operation at the present time, the plans being discussed would indicate that up-to-date studios will be developed throughout the country within a few years. These plans are now in the preliminary stage and it will be some time before all the details are worked out and actual construction starts.

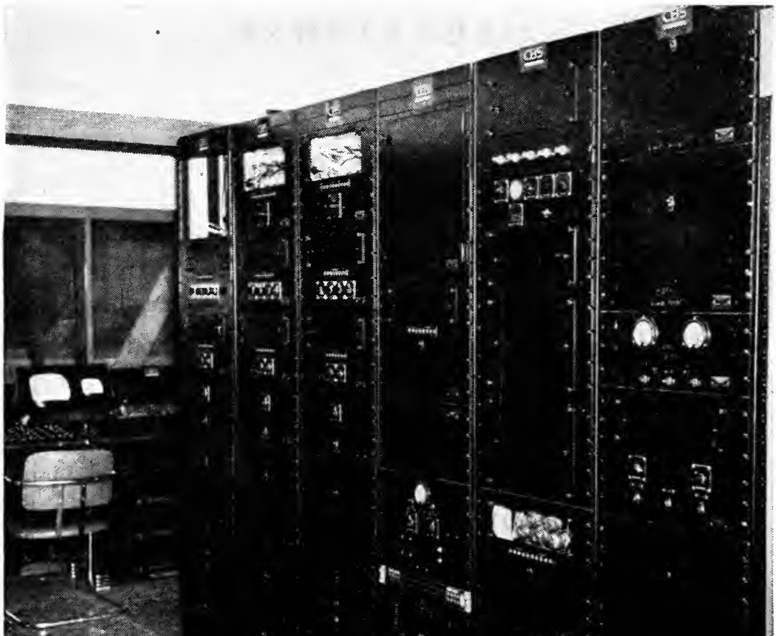
Chapter Four

STAGE AND CONTROL ROOM OPERATIONS

TELEVISION stage operations are far more complicated than standard studio broadcasting, the reason being that sound and sight must be co-ordinated and directed. Also the actors must memorize their parts, and scripts can only be used for news broadcasts or similar events. To telecast plays, musicals and other types of programs from a television studio requires expert directing.

The director is the mastermind of the entire operation and he usually works from the control room. As the operation is complicated, quite often an assistant director is used in the control room as well as a girl who keeps the program log. Directly in front of the director sit the sound and picture control men. These men are known as audio and video technicians or engineers—they control the sound and picture.

The audio technician in the control room is responsible for the sound pickup and he in turn has a man on the stage known as a boom-man. The boom-man controls the microphone by manipulating a long boom which extends over the stage. The microphone is hung on the end of this boom. This enables the boom-man to move the microphone around the stage and follow the various actors and actresses.



Courtesy of C.B.S.

TELEVISION CONTROL ROOM AMPLIFIER AND CONTROL EQUIPMENT

Courtesy of C.B.S.

TELEVISION CONTROL ROOM SHOWING MONITOR TUBES

The audio technician has his own control desk beside the video (picture) control desk. The equipment on this desk enables the audio engineer to switch from one microphone to another. He can also control the volume on any microphone by means of a volume control. Over his head, or near by, is a loud-speaker which enables him to hear the program as it is being sent to the transmitting station. As the control room is soundproof, he hears only what is being picked up by the microphones. Through the control room window he can watch the actors and his boom-man. His main function is to maintain the proper volume level. One or several microphones may be used, depending upon the type of program being transmitted. The audio engineer usually has telephone communication between his desk and his boom-man on the stage. The boom-man uses head phones to receive his instructions from the audio engineer. This leaves his hands free and eliminates the possibility of the instructions being picked up on the stage microphones.

Next to the audio engineer, inside the control room, sit the video engineers. There are two or more video engineers, depending upon how many cameras the control desk can handle. One of these engineers takes care of shading. He can adjust the contrast between the light and dark areas of the picture and correct other defects in the transmission system. This is done electronically by controls similar to the audio engineer's volume controls.

The other video engineer takes care of camera switching and adjusts the picture for intensity. He receives his instructions for switching cameras from the director seated behind him.

The video engineers can also switch from the cameras on the stage to film pickup. A regular motion picture can be shown as part of the program, or the entire program can be taken from film.

It is also possible with this arrangement to take certain scenes on film, such as outdoor shots, and switch to these during the program. This helps in allowing the actors time to change from one stage set to another.

Usually for a television program of any size, at least two cameramen are necessary. This allows for close-ups and long shots of the stage action. One camera may be mounted on a mobile camera boom and the other on a pedestal type of camera support. Two men are required to operate the camera boom, one man operating the camera and the other man adjusting the boom and moving the dolly on which the boom is mounted. The second man is called the dolly man.

The camera boom is used for most trick shots. It can raise the camera to a high elevation or drop it down, close to the floor. The camera boom can also be moved from side to side. The camera on the end of the boom can be tilted up or down and swung right or left, picking up a shot from any desired angle. The cameraman has a viewing screen inside the camera so he can focus and see the action the camera is picking up.

During rehearsals the director works out the various shots with the cameramen. For a dance routine he might want the camera boom to be shifted to several positions around the stage. The less mobile camera is used for close-ups of the various stars. These various shots are rehearsed before the program is put on the air. When the program is on the air the director can communicate with the cameramen or with a stage director who signals the cameramen when they are to change camera positions.

While two cameras are picking up the action, only one camera pickup is sent on to the transmitting station for transmission to your home. However, both pictures appear on the video control desk. Each camera is connected to the control room by separate cables. A monitor picture tube, which functions in the same way a direct-viewing receiving tube does, is used so that the video engineers at the control desk can view what each cameraman is picking up. These pictures can also be seen by the director seated behind the control desk.

By means of switching, either picture can be televised. The electrical impulses coming from either camera are connected by means of a switching system to the outgoing television line. This line, known as a coaxial line, is used to send the picture impulses to the transmitting station.

When this switching is done, an indicating light flashes on the camera. This light lets the stage director, the actors, and the various other members of the stage crew know which

Courtesy of C.B.S.

CAMERA ROOM

camera is being used for transmission, and eliminates the possibility of a camera being moved to a new position while it is on the air.

Camera switching can also be used for changing scenes. The camera which is not being televised can be moved over to another scene located on a different part of the stage. When the proper time arrives it is only necessary for the control room engineer to switch cameras.

Other members of the stage-operating personnel are electricians, property men, "grips," carpenters and scenic artists. The electricians handle and control all lighting as instructed by the director and cameramen. Property men take care of furniture, costumes and other stage properties. The "grips" move scenery and handle lights, and the carpenters build special sets. The scenic artist supplies the background for the programs.

To illustrate some of the stage operations, imagine a large television studio with a control room at one end. At the opposite end of the studio is a large television set, a replica of a railroad station. Near the sides of the studio, closer to the control room, are two additional stage sets. By arranging the sets in this fashion, all members of the operating staff in the control room can view all three sets. The director seated behind the operating staff can also view the three stage sets and watch the control board.

The set to the right of the control room is a living room scene. The set to the left of the control room is the interior of a taxicab.

The scene opens in the railroad station. A typical family is returning from a summer vacation. They are walking up the ramp into the main waiting room of the railroad station. For this shot the camera boom is used. The cameraman rides the boom, focusing the camera on the actors, while his dolly man gradually pulls the camera back as the cast walks up the ramp. In this way, he follows the action until the group stops in the main waiting room to have a discussion. While this is going on, the sound man has also been following the group with his boom, holding the microphone slightly above and in front of the actors' heads. Near the spot where the group stops is a television camera of the pedestal type. This camera is focused on the head of the person who is doing the talking, and is used for a close-up shot. The director in the control room has been watching the action picked up by both cameras by viewing the monitor tubes on the control desk. An indicating light shows that the picture being picked up by camera number one (the boom camera) is going on the air. As the group stops to talk, the director calls to the video man at the control desk to switch to camera number two, so that a close-up picture of the father talking to his son is transmitted.

The director now tells his stage director by phone that it is time for the boom cameraman to shift his camera over to the right where the living room scene is set up. The stage director signals the dolly man and he moves the camera to this scene. The cameraman focuses his camera on a maid who is cleaning up the living room. The close-up picture in the railroad station is still going out on the air. At this point the director instructs the video man to switch to camera #1, the camera that is picking up the living room scene. He also tells the sound engineer in the control room that he is switching scenes. The sound engineer throws down a switch which cuts in the microphone covering the living room scene. At the same time he throws another switch which cuts off the microphone being used on the railroad station set. In this way the sound pickup is switched from one scene to the other.

The actors and the number two camera, which is used for close-ups, are now instructed to move to the taxicab scene by the director through his assistant on the stage. The actors, the number two camera, and the microphone boom move over to the scene which is the interior of a taxicab. While this is going on the living room scene of the maid cleaning up the home is still being telecast. The family group take their places inside the taxicab. The close-up, number two camera is focused on this scene. The sound man moves his boom so that the microphone hangs over the actors' heads. This picture now appears on the video desk in the control room. The video engineer adjusts the brightness of the picture until he has the proper balance. The director tells the video man, handling the camera switching controls, to switch to number two camera, at the same time instructing the sound man to

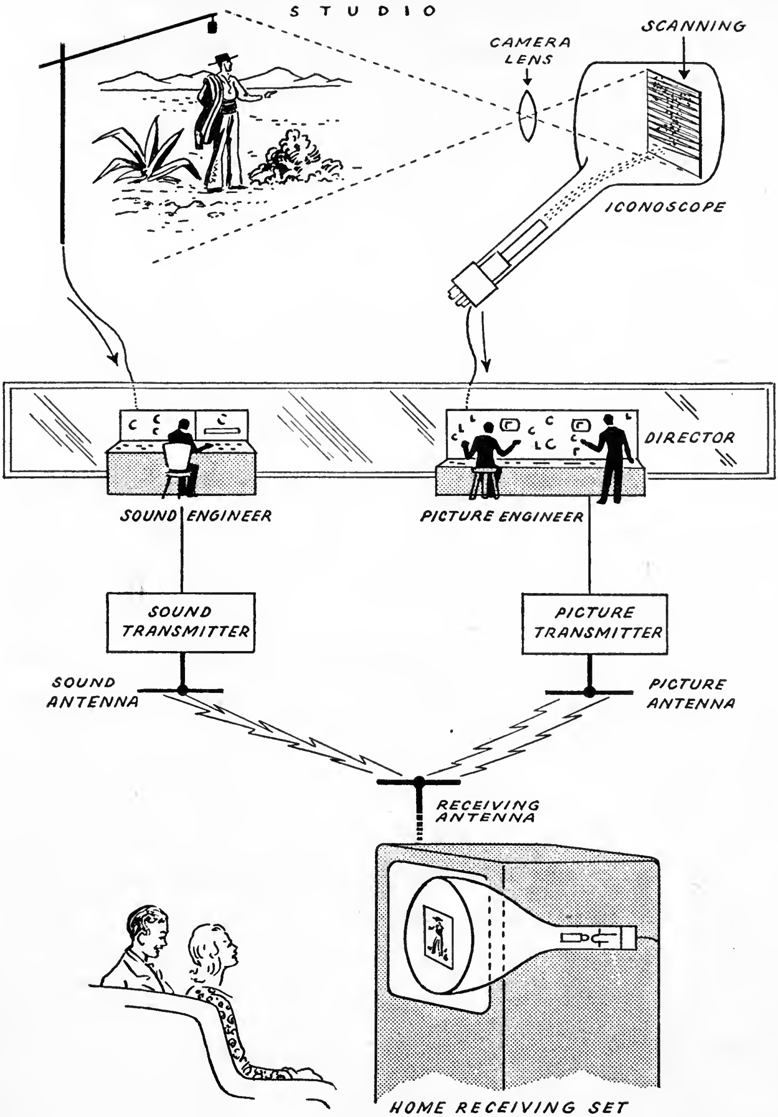
Courtesy of C.B.S.

TELEVISION STAGE OPERATIONS

switch his microphones so the pickup is coming from the taxicab scene. This scene is now telecast. The stage hands shake the taxicab so that it appears to be in motion. Scenery on a roller behind the taxicab is moved rapidly to create the illusion of the cab being in motion. Between conversations in the taxicab the action is switched back to the living room scene. In this way the person receiving the telecast can see what is occurring in both places.

While this is going on a man in the projection room is loading a projection machine with film. This film contains a picture of a scene taken the day before, an outdoor shot of the family group getting out of the taxicab and walking to the front door of their home.

In the taxicab scene the driver is going through the motions of stopping the taxi. The scenery behind the cab stops moving and the picture of a house appears. The cab driver climbs out and opens the back door for the family. The director is now watching this scene which is being telecast in the control room. Another scene appears on the number two viewing tube in the control room. This is the scene which was taken the day before on motion picture film. It is being picked up by a camera in front of the projection room and shown on one of the monitor picture tubes on the control desk. The director tells the video man to switch to this scene. He presses a button and the scene taken on film of the family leaving the taxi and walking toward their home is telecast. This allows time for the family group on the stage to move over



BLACK AND WHITE TELEVISION SYSTEM FROM STUDIO TO RECEIVER to the set which represents the interior of their living room. The close-up camera also moves over to this scene. All the equipment is now set up in front of this scene for the final act of the play. Again the director gives his instructions and the scene is switched from film back to the live pickup on the stage.

The person viewing this scene on a television home receiver would not be aware that the actors and equipment had moved from scene to scene. They first would see a picture of the railroad station, then what was going on in the family's home and then they would see the family traveling in a cab. The viewer would follow their progress to the living room scene without being aware of operations behind each part of the play.

In order to produce a picture of the type just described, hours of rehearsal are necessary so that all operating personnel can move with split-second timing, each person knowing exactly what to do when he receives his cues. This is one of the reasons why television is a lot more complicated than normal broadcasting. The equipment is also more complicated to design and operate.

Chapter Five

TELEVISION SOUND SYSTEM

THE sound system used in television is quite similar to the sound system used in ordinary broadcasting. There are only two major differences. One of these differences occurs in the method of picking up the sound with a microphone. The other occurs in the sound end of the television transmitter. As the sound originates on the television stage, we will describe the operation of the microphone first and then follow the sound transmission to the engineers' control desk and the transmitting station.

In radio work the actors or actresses usually stand directly in front of and close to the microphone. This, of course, is the simplest way of picking up a program. In television pictures, the method is not practical, as a microphone appearing in the picture would spoil the illusion. Microphones are, therefore, kept out of the television picture except in certain cases where it is desirable to have them appear.

This is accomplished by a microphone boom, of which there are numerous types. The boom usually consists of a three-legged stand mounted on wheels so that it can be easily moved around the studio. An upright on this stand supports the horizontal boom. On the end of this long boom the microphone is mounted. This enables the engineers to project the boom over the stage area, high enough so that it does not appear in the television picture. The microphone is thus placed overhead and slightly in front of the actor. As the actor has to be free to move about the stage, the microphone boom has to be quite flexible. It should be capable of moving the microphone to any location on the stage, raising, lowering and rotating the microphone as the action directs. The better microphone booms can accomplish all these things with a single operator. The operator of a microphone boom is called a boom-man and he is part of the stage crew.

Booms of this type are capable of a number of adjustments. The vertical member that the boom pivots on telescopes so that the boom can be raised or lowered by means of a crank. The boom not only pivots on this vertical member, but it may also be tipped up or down. The horizontal boom on which the microphone is mounted is also telescopic. By turning another crank this member can be extended to cover most of the stage area. Booms of this type usually have a floating counterweight to balance the boom as it is extended. The microphone is mounted on a pivoting device at the end of the boom. This rotating bracket is controlled by means of cables connected to a lever located near the supporting frame.

The operator stands by the base and makes any necessary adjustments to the microphone by manipulating the various cranks and levers. By doing this the operator can follow the actors and actresses around the stage, usually keeping the microphone in the same relative position with respect to the actor.

The microphone used with this boom may be any one of several types. While there are a good many different types of microphones manufactured, they all fall into three general categories as far as sound pickup is concerned. The three types are called uni-directional, bi-directional and non-directional. The uni-directional microphone is only sensitive to sound coming from a single direction. This means the actor must be facing the sensitive side of the microphone. If he should move to the side or rear of the microphone, very little sound would be picked up. The bi-directional is sensitive on the front and the back, but not at the sides. In this case, one person can stand in front of the microphone and another at the back and both be heard on the receiving end. The non-directional type picks up sound entering the microphone from any side. R.C.A. manufactures a microphone used in radio to a considerable extent which can be converted, by means of a switch, into any one of the three types just described.

The main function of a microphone is to convert sound waves into electrical energy. When the microphone does this, it creates electrical energy which has the same general characteristics as the original sound. Sound passes through the air as ripples do on water and that is the reason we think of sound in the form of waves. The frequency of these waves determines the pitch of the sound. As we run up the scale on a piano, the frequency of the waves increases as the pitch of the sound does.

When we strike a note on the piano, a string inside vibrates. This string will vibrate a certain number of times per second. It also causes the sounding board on the piano to vibrate the same number of times per second. This, in turn, makes the air around the string and the sound board vibrate in the same manner. If the piano string vibrates 256 times per second, which is middle "C," then the air vibrates 256 times per second creating a sound wave. The number of times per second a sound wave vibrates is called the frequency of the sound wave. The frequency varies as the sound does —the higher the frequency, the higher-pitched the sound. When two or more notes are struck on the piano, the piano will produce a sound which is a combination of various frequencies. The piano normally covers a sound frequency range of about 30 cycles to 6,500 cycles per second.

The sound frequencies produced by the normal speaking voice cover a range of about 100 cycles to 10,000 cycles per second, the female voice producing higher frequencies than the male. The male voice covers the range from 100 cycles to 8,500 per second, the female range being about 150 to 10,000 cycles per second. Musical instruments have a greater range, starting at about 40 cycles and going up to 15,000 cycles per second.

There are audible and inaudible sounds. The human ear is not capable of hearing all of them. In fact, sound having a frequency above 20,000 cycles cannot be heard by most people. Few people can hear above 15,000 cycles per second. This hearing range normally decreases as a person gets older. Some animals, such as dogs, can hear sounds above the human range. In certain electronic work, such as submarine detection, sound frequencies above the audible range are used.

The main function of a microphone is to convert these sound frequencies into electrical waves of the same frequency. This is done in the microphone by first converting these sound waves into mechanical vibrations of the same frequency. These mechanical vibrations are then converted into electrical energy which varies in frequency in the same manner as the original sound.

Certain sounds can be of a single frequency though most sounds we hear are a combination of varying frequencies. If we think of a sound of a single frequency, it is simple to understand how a microphone functions. A pure sound such as a 500-cycle tone causes a diaphragm inside the microphone to vibrate at the rate of 500 cycles per second.

This diaphragm is caused to vibrate by the varying pressure created by the sound wave. The diaphragm causes a current to vary in the microphone at the rate of 500 cycles per second. We now have an electrical current which varies in frequency the same number of cycles per second as the original sound wave.

If the original sound was a combination of frequencies such as 500 cycles, 650 cycles and 1,200 cycles then the microphone would convert these frequencies into electrical energy of the same frequencies.

This electrical energy, after it has been amplified, can be applied to a loud-speaker. The loud-speaker changes this electrical energy back into sound waves. The energy is applied to a coil of wire which is attached to the speaker diaphragm. This coil moves as the current varies because of a magnet located in the speaker. As the coil moves, it causes the speaker diaphragm to move. This changes the electrical frequencies back into sound frequencies.

All microphones do not use the same mechanical or electrical device to change sound waves into electrical waves of the same frequency. Generally speaking, they all accomplish the same result, but some are more sensitive than others. Microphones will only convert sound waves into electrical waves over a certain frequency range. The less sensitive microphones may only cover a range of 100 cycles to 5,000 cycles per second. Sound above this range cannot be transmitted. This affects the quality of the sound when it is reproduced by a loud-speaker. Cymbals produce a sound which contains many high frequencies, so a microphone with a narrow frequency range cannot transmit this sound accurately. Therefore, when the sound of cymbals is picked up by such a microphone, it will not sound natural on the receiving end because the high frequency part of the sound is missing.

High quality sensitive microphones with a wide frequency range (60 to 10,000 cycles) are used to a great extent in television and radio work. However, less sensitive "mikes" have an advantage for certain types of work. Wide frequency range "mikes" are used to pick up orchestrations. Less sensitive "mikes" are often used to pick up voice frequencies produced in normal conversations. The speaking voice produces more low frequency sounds than high. The low frequencies in voices are more pleasing to hear and therefore, if the high frequencies are eliminated by the microphone, a better effect is produced even though this is not accurate reproduction. In a good many radio studios only highly sensitive "mikes" are used, but they are equipped with an electrical device which can make them less sensitive to high frequencies. This device is connected to the microphone by means of a switch so it may be cut in or out. It is used to pick up speaking voice frequencies, but is cut out by means of the switch when the microphone is used for an orchestra pickup.

Devices of this type are called filters. They filter the sound, eliminating any undesirable sounds falling in a certain frequency range. Actually, filters eliminate electrical frequencies as the device is electrical. More complicated filters are used to produce certain sound effects. Some of these filters are adjustable—they can be set to filter various bands of frequencies. These filters consist of coils of wire called an Inductance, and electrical devices called Condensers. When these units are properly placed in an electrical circuit they act as a filter. The frequencies that are filtered by such a circuit are dependent upon the value of the inductance and the capacitance. By varying the value of one or both of these devices the filtering characteristic can be changed.

One of the effects that can be produced by a filter of this type is to make a person sound as if he were talking on a telephone. You have probably heard this effect on your radio when the person in the television or radio show is supposed to answer the telephone. Actually, the actor does not even move away from the microphone. The sound-effects man provides the telephone bell, and the control room engineer cuts in the filter changing the person's voice so he sounds as if he were talking on the telephone. The reason a person sounds different over a telephone is because a telephone only reproduces sounds of low frequency.

On a television stage, one or a number of microphones may be used, depending upon the number of actors and the type of show. In some cases, two booms may be needed,

Courtesy of N.B.C.

MICROPHONE BOOM

with one or two "mikes" concealed on the set as well. Each microphone is connected to the control room by means of a separate electrical cable. These cables usually plug into the studio wall. The wall plug is connected to the sound control desk inside the control room. Each of these lines coming from the microphones is connected to a separate microphone amplifier located in the control desk or near by. These microphone amplifiers usually contain one or two electronic vacuum tubes. These units are used to amplify the weak audio signal coming from the microphone. Each line leaving these amplifiers is connected to a switch and volume control located on the front of the engineer's control desk. The switch is provided so the engineer can cut off any microphone he does not wish to use. The volume control works on the same principle as the volume control on your radio receiver. It is used to control the volume of the signal coming from the microphone. Then each of these individual microphone volume controls is connected to a master volume control. This control regulates the volume on all the microphones. The individual controls enable the engineer to balance the volume between the various microphones to produce any desired effect. When the engineer gradually reduces the volume on a given control, the sound being picked up by that particular "mike" seems to fade into the background. When this is done it is called "fading" and the sound being picked up by any one of the microphones may be "faded" in or out. The master volume control can be used in the same manner to produce fading effects on all the microphones simultaneously. This might be done when the television camera is backed away from a scene, giving the viewer the effect of moving away from the scene.

One of the main functions of the audio engineer in the control room is to maintain the proper volume level at all times. For this purpose, he has a volume indicator—this unit is an electrical meter which actually measures the flow of current. It is marked off in volume units and decibels, the measuring unit used to determine the loudness of sound.

By watching this meter and adjusting his volume controls the engineer can maintain the proper volume level. The engineer also has a loud-speaker which enables him to hear the program as it will sound on the receiving end. This can be quite different from the way it sounds on the television stage, due to the sensitivity of the microphones, the placement of "mikes," the sound effects which may be added, and the balancing of the sound which the engineer controls.

After the sound signal leaves the engineer's control desk it is sent over a special line or wire to the transmitting station. There are two ways this sound signal (audio) can be sent to the transmitting station. It can be sent over a telephone line, which is the system normally used in radio broadcasting, or it can be sent over the same line as the picture signal. This latter system is a new method developed during the war. Both picture and sound are mixed together in the control room and sent to the transmitting station over a special line called a coaxial cable. This newer method is now being used in conjunction with colored television and will be described more fully later on.

The pre-war system which is still being used for black and white television transmission sends the signal to the television transmitter by telephone lines. The pre-war black and white system requires two transmitters and two antennas, one for sound and one for picture. The new color system only requires one transmitter and one antenna. When the sound signal reaches the transmitting station it passes through another control desk. This control desk has a volume control and a volume indicator so the transmitter engineer can check the volume level and make any necessary adjustments. He is also equipped with a loud-speaker so he may listen to the program. As he has trained his ear to listen mainly for transmission defects, he rarely hears the program.

Usually the engineer can switch the monitor speaker so that he can listen to the program coming from the studio or listen to it after it has passed through the sound transmitter. In this way, if he detects any trouble, he can tell whether the transmitter is the cause or whether the trouble is occurring before the program reaches the transmitter.

The transmitter develops a special signal called a carrier wave. The sound coming from the studio microphones in the form of electrical waves is superimposed on the carrier wave. During this process both the carrier wave and the sound signal have been amplified by the transmitter. The method that is used to combine these two signals decides the type of transmission.

Formerly commercial broadcasting always used a method called Amplitude Modulation. There is a newer method called Frequency Modulation, sometimes known as static-free radio. This latter method is used for black and white television. The different methods of transmission will be described separately.

After these two signals are combined (the carrier wave and the sound signal) they are fed to an antenna system. There are many different types of antenna systems but the antennas used for television work are much smaller than the ones used for commercial broadcasting. These antennas radiate the energy that is developed by the transmitter in all directions and it is picked up by the antenna on your receiving set.

The receiver separates the carrier wave from the sound signal, leaving the sound signal (audio) in the same form in which it left the studio microphone. This signal is there amplified and fed to the loud-speaker in the receiving set. The speaker converts the signal back into sound again.

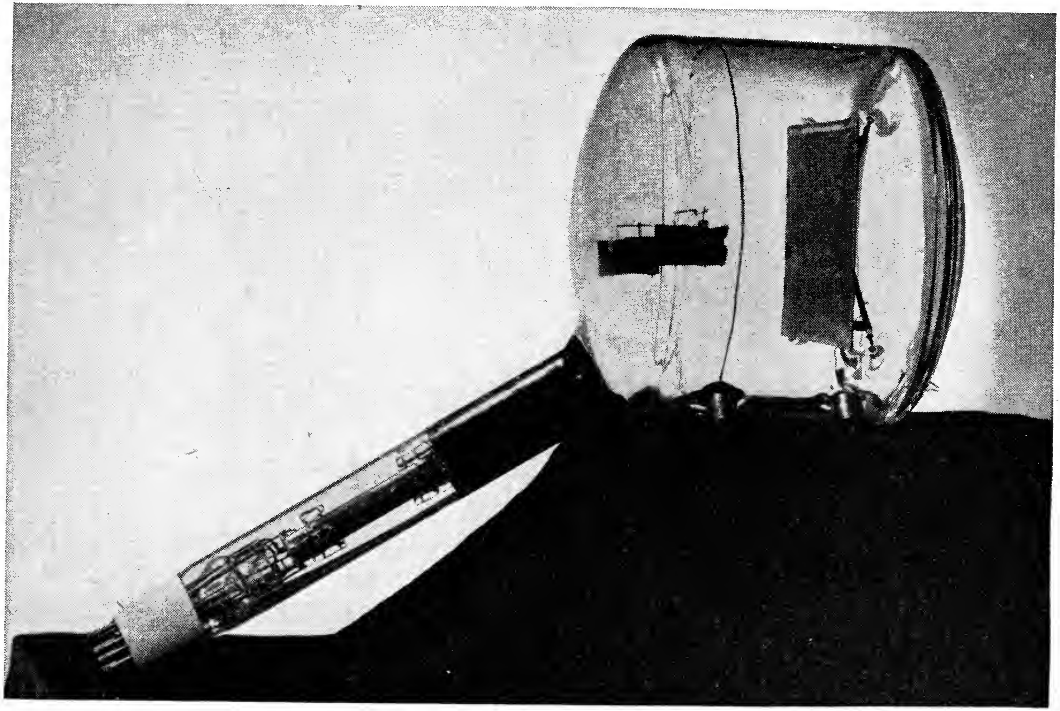
Your receiver antenna picks up the carrier waves for both picture and sound. These two signals go through several electronic stages before they are transformed back into sound and picture. The television receiver separates these two signals so that one section of the receiver reproduces the sound signal while the other part reproduces the picture. (See Television Receiver.) The new color method of transmission uses a single carrier wave for both sound and picture. This is an entirely different method of transmitting sound and picture, as you will see later on.

Chapter Six

THE ELECTRONIC TUBE

THE heart of all electronic apparatus such as radios, electric phonographs, radar, various communicating systems and television is the electronic vacuum tube, or "valve" as the English call it. Your radio set contains a good many of these vacuum tubes with which you are probably familiar. These tubes are used for various purposes, but one of the main functions is to amplify a weak radio signal. Television also uses these tubes to amplify weak television signals that produce the picture on the television receiving screen. Television utilizes these tubes for various other purposes, including a very special tube which actually produces the television picture.

Before we can proceed with the basic operating principles of an electronic tube, it is important to know what a radio or television signal is. One of the simplest types of radio signal used is the dot and dash. This code method was used in the early days of radio and is still being used to a considerable extent. Various combinations of dot and dash indicate the different letters of the alphabet. This code is known as the Morse Code. In other words, in this case the electrical energy which is dissipated into space by a transmitting station is sent out in the form of dots and dashes. This is only one type of signal. Voice and music are transmitted by a different type of radio signal. In fact, there are two widely different radio signals used today for transmitting voice and music to your home. One of these signals is known as Amplitude Modulation and the other, a newer method, is known as Frequency Modulation, commonly called F.M. Television transmits its picture by sending out a special type of radio signal. These various signals, about which you will learn more, are very weak by the time they reach your receiving antenna and, therefore, must be amplified before they can be utilized to reproduce either sound or picture. This is one of the main functions of the radio tubes in your set. This is also the main function of the various vacuum tubes used in the transmitting station which transmits its signal to your home. However, the tubes used in television transmitting stations are many times larger and more powerful than the type used in your receiver. These large tubes used by transmitting stations handle so much power that they would melt and burn out if they were not cooled off by water or a blast of cool air.



Courtesy of R.C.A.

STANDARD ICONOSCOPE TELEVISION CAMERA TUBE. THIS TUBE IS USED TO DISSECT THE TELEVISION PICTURE

The simplest vacuum tube is the rectifier tube. This tube is utilized to change alternating currents (A.C.) to direct currents (D.C.). Direct current is an electrical current flowing in a single direction. This is the type of current produced by a flashlight battery. When you turn on a battery-operated flashlight, the current flows from one terminal of the flashlight through the filament of the flashlight to the other terminal. The current travels in a single direction and is, therefore, called direct current (D.C.). Batteries, whether dry cell or storage type, always produce direct current. Alternating currents are produced by electrical generators; direct current can also be produced by this method. Alternating current (A.C.) does not flow in a single direction as direct current does, but changes the direction of flow intermittently. Alternating current generators cause the current first to flow in one direction, through the wires of an electrical circuit, then to stop and start flowing in the opposite direction. These changes in direction of current flow occur quite rapidly. The number of times per second the current changes its direction of flow determines the frequency of the alternating current. If the current changes its direction of flow sixty times a second, which is quite common, this is known as 60-cycle A.C., a cycle being one complete oscillation. The current starts at zero and gradually builds up as it flows in one direction through the circuit. The current then diminishes to zero and starts to flow and build up in the opposite direction before returning to zero. This is one complete oscillation or cycle and it is completed in a fraction of a second. As we have said, the number of these cycles completed per second determines the frequency of the alternating current. If a cycle is complete in $\frac{1}{50}$th of a second then it is 50-cycle A.C. current.

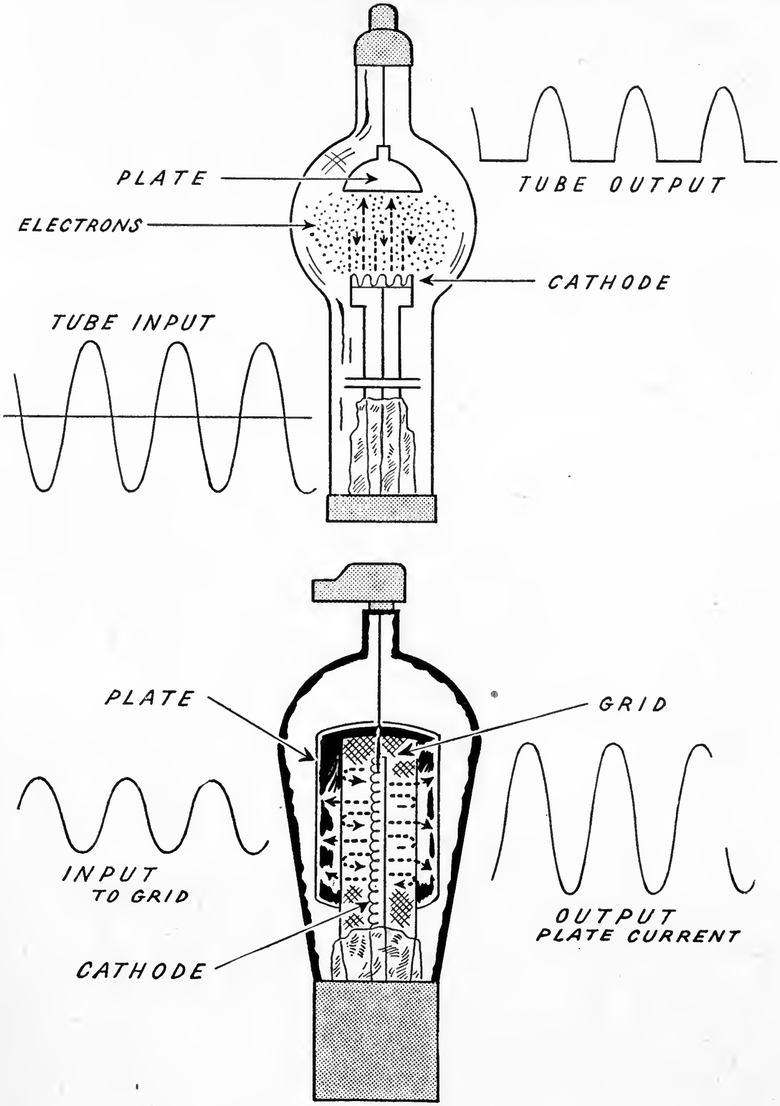
Your radio receiver probably contains a rectifier tube if it is operated by ordinary A.C. house current. The other tubes in your receiver require D.C. to operate, so the rectifier tube is necessary to change A.C. to D.C. These rectifier tubes usually have two or three electrodes and they function by negative electrons that are given off by one of the electrodes.

There are positive and negative electrons. When an ion, which consists of positive and negative electrons, loses one or more of its negative electrons, it is considered to be a positive electron. The negative electron is a minute charged particle, much smaller than the positive electron, and it travels at a much greater velocity. These negative electrons are utilized to control the flow of current through a vacuum tube; they are also used in the television picture tube to produce the picture that you see on the television screen. It is by controlling these electrons inside a vacuum that the great accomplishments in radio, radar and television have been achieved.

The rectifier tube usually contains two or three elements. We will describe the function of a two element tube (Diode) as it is the simplest type. One of the elements in this tube is a filament which glows or lights when the proper current is applied to it. The filament in an ordinary electric light bulb does the same thing except that it gives off more light. This filament inside the vacuum tube is usually called a cathode and it emits large numbers of negative electrons when it is heated to the proper temperature by an electric current. The second element in the tube is the plate (Anode) and it acts as an electron attractor when a positive current is applied to the plate. In other words, when the proper currents are applied to the filament and plate, the negative electrons given off by the filament (Cathode) are attracted to the plate (Anode).

However, this attraction of electrons to the plate only occurs when the plate is made positive by an electric current, that is, when the plate is more positive and less negative than the filament (Cathode). If the current applied to the plate is negative it repels the negative electrons so the electrons do not travel from filament to plate. Now if an alternating current which is changing from positive to negative, such as a 60-cycle A.C., is applied to the plate, then the electrons are only attracted to the plate during the time the current is positive in respect to the filament. During one complete cycle, the current as it flows in one direction is positive and as it reverses its direction it becomes negative.

So, during one half of this cycle when the current is positive, electrons pass from the filament (Cathode) to the plate. This causes the current to flow through the tube as the negative electrons strike the plate. The second half of the A.C.



RECTIFIER AND AMPLIFIER TUBE OPERATION

cycle makes the plate become negative and repels the electrons given off by the filament. When this occurs no current flows through the tube as it will only flow when the electrons pass from filament to plate. Thus this tube only allows the current to flow during one half of the A.C. cycle or when the current is flowing in one direction. Now if the current is only allowed to flow in one direction, then it becomes Direct Current or D.C. This produces what is known as pulsating D.C. as no current flows during the time the current is negative. These pulses are smoothed out by an electrical filter circuit so they do not interfere with the operation of the television receiver. This type of tube is known as a half wave rectifier as it rectifies one half of the A.C. cycle. There are three-element rectifiers which operate on the same fundamental principle except that they rectify the complete cycle. These tubes are known as full wave rectifiers.

The rectifier tube just described is used in radio or television receivers to supply D.C. to the other tubes in your receiver. Alternating current cannot be used as it interferes with the radio or television signal.

The other tubes in your receiver are used to amplify a weak radio or television signal, to rectify a signal or to produce high frequency alternating currents. While these tubes are more complicated they still function by controlling the flow of electrons between elements inside the vacuum tube. They are used for many purposes, but one of the simplest uses is to amplify the audio signal produced by a microphone so that it can be used to drive a loud-speaker. This is the use it is put to when employed in a public address system. It is used in this way when a singer needs a microphone on the stage to amplify his or her voice. These tubes are also used in the television receiver to amplify the weak sound and picture signals.

Tubes of this type are called Diode, Triode, Tetrode, Pentode, etc., depending on how many elements the tube contains, a two-element tube being a diode; a three-element, triode, and so forth.

To describe the operation of these amplifying tubes we will take the simplest amplifying type, a triode of three-element tubes. This tube contains a filament (Cathode), a plate (Anode) and a grid. The filament can be one of two types, either a filament which is heated by current passing through it, or a small cylinder which is heated by an internal filament. This latter type is employed when A.C. is used to heat the filament. These two types are known as the filament and heater type cathodes respectively.

The grid is located between the filament (Cathode) and the plate (Anode). It usually consists of an open spiral or mesh of fine wire. The electrons passing from filament to plate pass through this grid. The grid is utilized to control the flow of electrons between the filament and plate. When the proper currents are applied to this grid it acts as an automatic valve controlling the flow of electrons to the plate.

If a small current is applied to this grid making it negative then it will repel the electrons which are given off by the filament. This is true even when a positive current is applied to the plate. When the grid is negative it repels the electrons before they can pass through the grid screen to the plate. However, if the current in the grid becomes less negative (more positive) some of the electrons will pass through the grid to the plate. As it turns more to the positive side, more and more electrons are allowed to pass through the grid to the plate. The current flowing in the plate circuit in the amplifying tube, as in the rectifier tube, is dependent on the electrons being attracted to the plate. If no electrons are allowed to reach the plate then no current flows in the plate circuit. If small numbers of electrons reach the plate then a small amount of current is allowed to flow in the plate circuit. If a large number of electrons is allowed to reach the plate then a large current flows in the plate circuit. So the grid, by controlling the flow of electrons, also controls the current that flows in the plate circuit. A comparatively small amount of current applied to this grid controls a rather large current in the plate circuit. The grid of a vacuum tube is usually thought of as the input and the plate as the output.

Let us imagine a microphone is connected by an electrical circuit to the grid of this tube. The electrical signal from this microphone is very weak but it does cause the current to fluctuate in the grid circuit of the vacuum tube. This signal is changing from positive to negative, and changes the flow of electrons between the cathode and the plate. In fact the electrons will fluctuate in the same manner as the current coming from the microphone. This causes the current applied to the plate to change in a similar fashion. The plate current is a lot more powerful than the current flowing in the grid circuit. So we now have a current which has the same characteristics as the original current coming from the microphone except that it is much stronger. This can be repeated by coupling this plate to the grid of another tube, thereby amplifying the signal again, a process called a two-stage amplifier. By doing this several times with three or four tubes the signal can be applied to a loud-speaker and reproduced as sound again.

Very large amplifier tubes are used in television transmitters to step this signal up even more so that the energy can be radiated by an antenna system.

A very useful tube in radio and television is the cathode-ray tube. In fact, the tube used to reproduce the television picture in the receiver is a similar type of tube. The cathode-ray tube is used in radar equipment to detect and locate planes, ships and other objects. To transmit a television picture, currents of much higher frequencies than ordinary 60-cycle A.C. house current must be generated. Various frequencies, some as high as 400,000,000 cycles per second, are used to transmit the picture. The television camera tube generates currents whose frequencies may exceed 4,000,000

Courtesy of R.C.A.

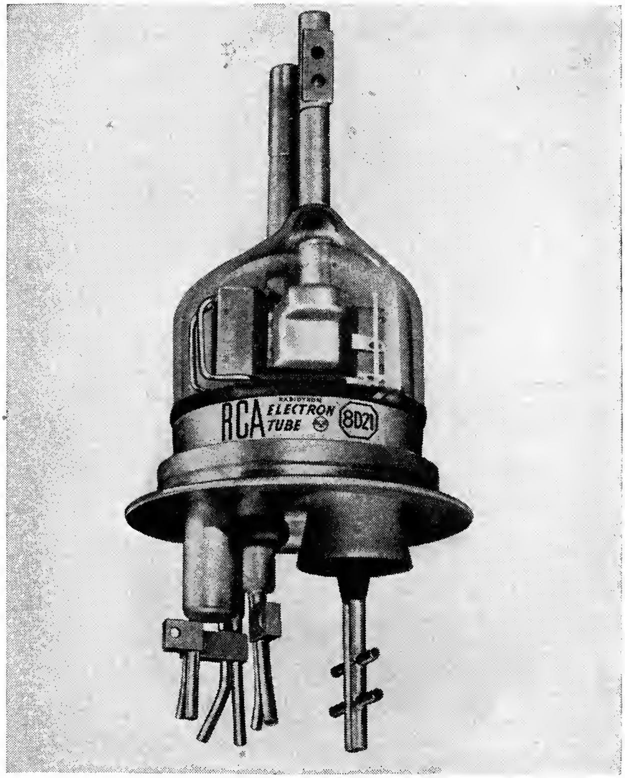
MODERN DIRECT VIEWING RECEIVING TUBE

cycles per second. The cathode-ray tube is used in television to analyze current of various frequencies. When it is used in this manner it is called an oscilloscope. This is a visual method of checking alternating currents. The current characteristics are traced out on fluorescent screens so they are visible.

The cathode-ray tube is a funnel-shaped glass vacuum tube. A special fluorescent material on the inside of the large end of the tube forms the viewing screen. The neck or narrow end of the tube contains the electrons. The elements in this end of the tube form an electron gun which generates a tiny stream of electrons and propels this stream toward the screen at the other end of the tube. When these electrons strike the fluorescent screen, a bright spot of light is produced. This bright spot can be white, green, yellow or blue, depending upon the ingredients in the fluorescent screen material.

The elements in the small end of the tube consist of a cathode, grid, two anodes and four deflecting plates. The cathode supplies the electrons, the grid controls the intensity of the electronic beam. The first anode accelerates and narrows the beam, the second anode further increases the velocity of the electronic beam. At the point where the tube widens there are two sets of deflecting plates. One set of plates is used to deflect the beam horizontally and the other set is used for vertical deflection. In large tubes of this type, coils are used instead of deflecting plates to control the electronic beam. When coils are used, they are mounted externally, close to the glass container.

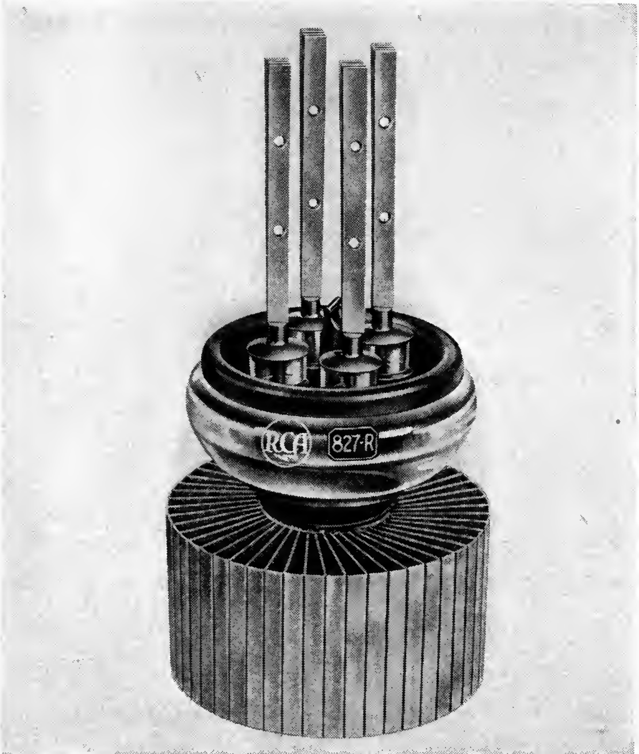
When currents with varying voltages are applied to the deflecting plates, such as alternating currents, they cause the electronic beam to be deflected. The deflection varies as the voltage of the current varies. If the varying current is applied to the horizontal deflecting plates then the beam will move back and forth. The bright spot which this electronic beam forms on the fluorescent screen will then move back and forth also. If 60-cycle current is applied, the spot will move back and forth at the rate of 60 times a second. This is so rapid that the spot appears as a horizontal straight line across the screen. Now, if the 60-cycle current is applied to horizontal and vertical deflecting plates, the spot will travel across the screen and rise and fall as the current varies. This produces a white line in the form of a wave on the fluorescent screen. The oscilloscope which uses this cathode-ray tube for analyzing currents can be adjusted so one complete cycle or several appear on the screen. All types of alternating current can be analyzed by this tube. In fact, it is used quite often in the television control room to analyze the complicated signal sent out by the television camera. In this case the signal appears as many complicated waves. As objects move in front of the camera the complicated waves appearing on the screen of this cathode-ray tube change quite rapidly. If desirable, this complicated wave can represent only a part of the complete picture as it is being transmitted instead of the whole. In television control rooms small cathode-ray tubes are mounted on the control board beside the monitoring tube where the television picture appears. If there is picture distortion, quite often the cause of it can be analyzed by this tube.



Courtesy of R.C.A.

NEW TYPE WATER-COOLED AMPLIFIER TUBE WHICH IS USED FOR VERY HIGH FREQUENCY WORK

Vacuum tubes are also used to create alternating currents of various frequencies. These alternating currents are used for different purposes. When an electrical circuit containing a vacuum tube is used to produce alternating currents it is known as an oscillator because it produces currents which



Courtesy of R.C.A.

AIR-COOLED TYPE OF TRANSMITTING TUBE

oscillate. Vacuum tube oscillators of this type are used in television transmitters to produce the signal that carries the program to your home.

The size of vacuum tubes varies considerably, depending upon the purpose for which they are designed. In lightweight portable equipment, tubes as small as acorns are used. These are known as Acorn Tubes. Then there is the common glass or metal tube which you find in your television or radio set. This type you have probably seen. There are tubes designed to operate at various voltages. The largest of these is the air- or water-cooled type used in television and radio transmitters. Some of these tubes are ten or twelve inches in diameter and two or three feet long.

The air- or water-cooled tubes are a combination of metal and glass. The upper part where the electrical connections are made is glass—the lower part which contains the filament, grid and plate is metal. The plate is made in the form of a metal tube housing the grid and filament. One end of this tube is sealed to the upper glass partition; the lower end is closed. When water is used for cooling, this tubular plate is submerged in cool circulating water.

Air-cooled transmitting tubes are similar in construction except that radial cooling fins are used to absorb the heat given off by the plate (Anode). Cool air is forced over these cooling fins at high velocity to keep the tubes at their proper temperature. Some of these large transmitting tubes cost anywhere from $1,200 to $1,600 each.

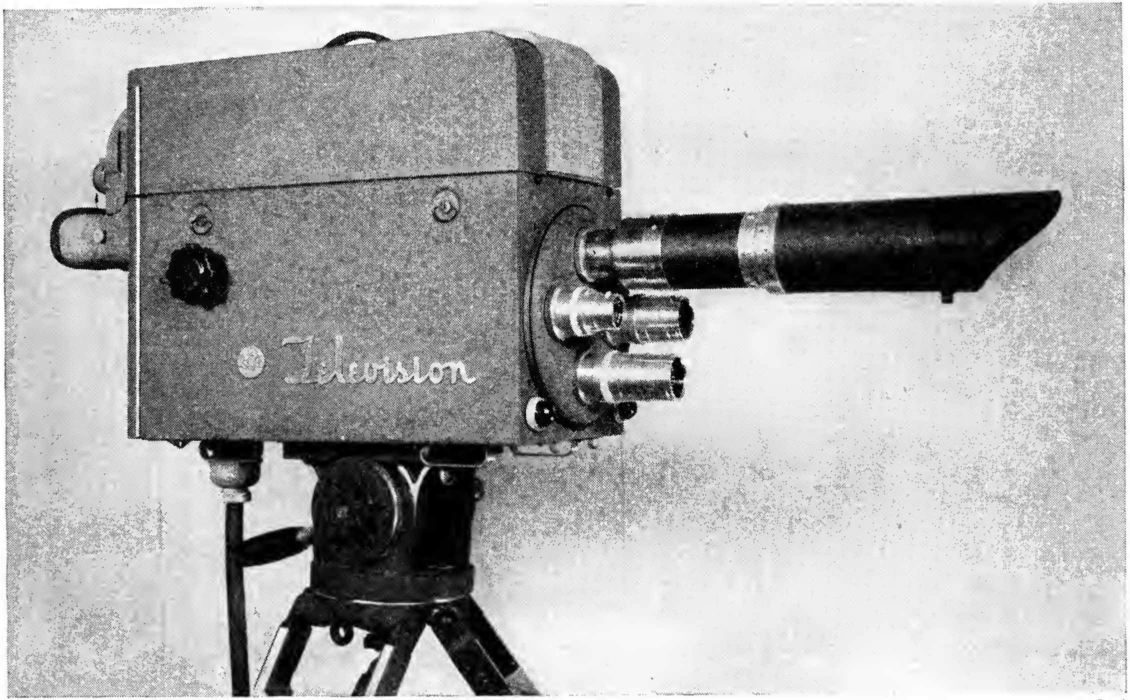
Chapter Seven

TELEVISION CAMERA

THE television camera in some respects is similar to a motion or still picture camera. The same type of lens system is used in a television camera, minus the shutter. The main function of a camera lens system is to project an image or picture on a light-sensitive film or plate.

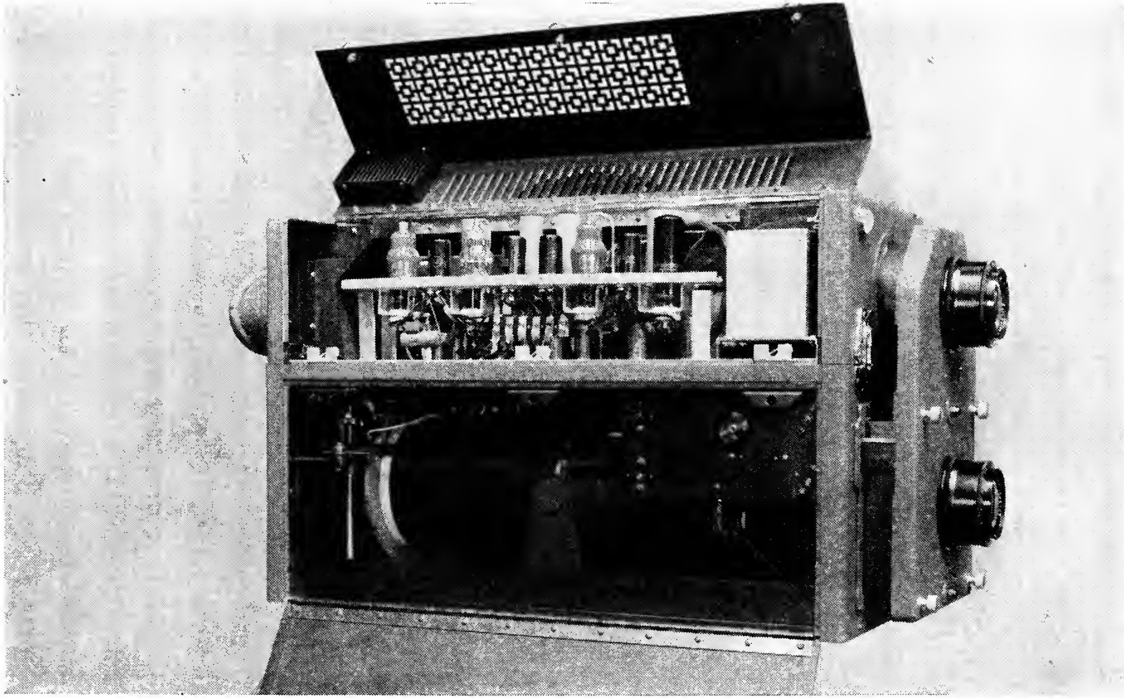
If you could see inside your own camera at the moment the shutter opens and closes you would find that the picture you are taking is projected on the film inside of the camera. Professional photographers use ground glass in the back of their cameras so they can actually see the picture that is projected. After they have adjusted their camera properly they insert the film in place of the ground glass.

The ordinary still picture box camera usually has what is known as a fixed focus lens. This type of lens is not adjustable and is set to focus on an object a certain number of



Courtesy of R.C.A.

TELEVISION CAMERA SHOWING SPECIAL TURRET LENS MOUNTING. LONG LENS IS TELESCOPIC AND IS USED PRINCIPALLY AT SPORTING EVENTS feet from the camera. Objects which are nearer or further away are slightly out of focus or blurred. More expensive cameras have adjustable lenses that can be focused on objects at various distances from the camera. If you study a photograph you will find the main object in the picture is quite sharp and clear and all objects behind or in front of the main object are slightly blurred. The lens is said to be focused on the object which is sharp and clear. With adjustable lenses there are two ways of focusing the camera. Usually there is a scale in feet on the camera and an indicating marker to show you at what distance from the camera the object in focus is. With this type of camera you measure or estimate the distance from the object you wish to photograph to the camera. You then move the lens until the indicator shows it is focused at that distance. You set your shutter speed and take the picture and hope you have estimated the distance correctly. Most professionals prefer to focus on ground glass so they can be sure which objects are in and which are out of focus. Some still picture cameras have twin lenses—one lens projects the picture on ground glass, usually located in the top of the camera, and the other lens projects the picture on the film. With this type of camera it is possible to focus and see the picture right up to the time you click the shutter. This type of camera is known as a twin lens reflex. Most television cameras are similar to this type of camera—that is, they are equipped with two lenses, one for picture transmission and the other for viewing



Courtesy of R.C.A.

INSIDE VIEW OF STANDARD PICKUP CAMERA

and focusing.

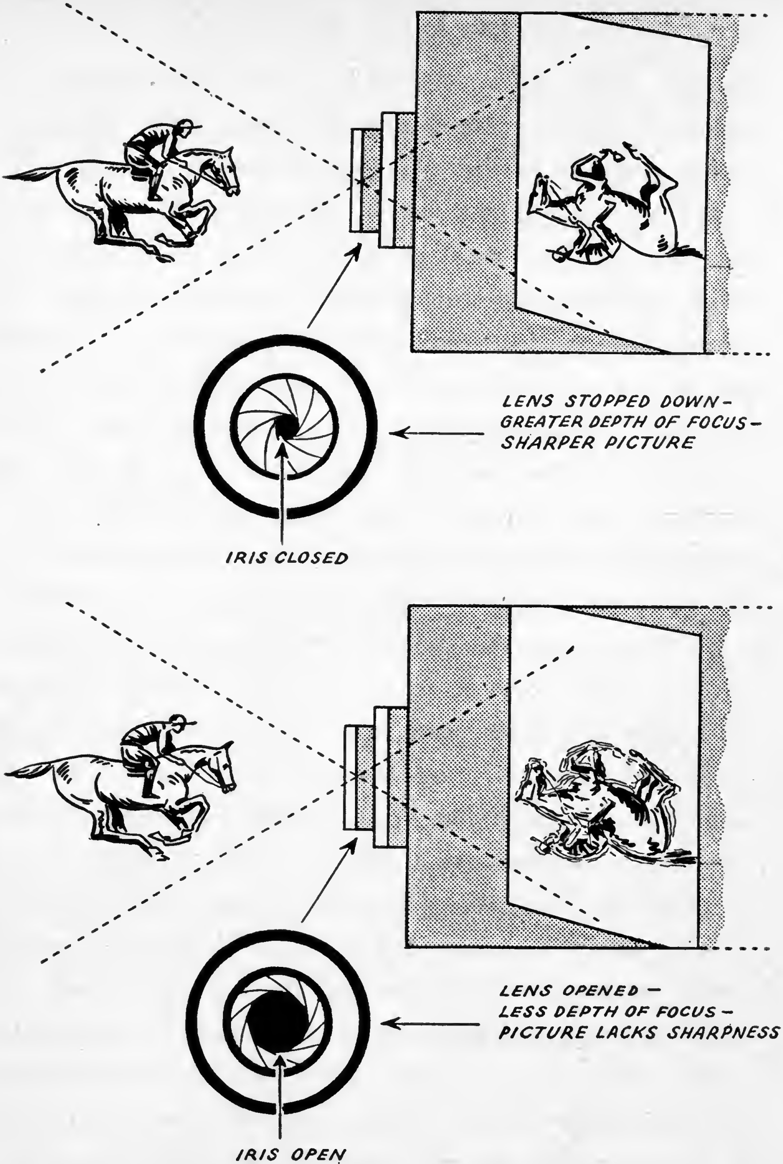
The R.C.A. Iconoscope television camera, equipped with twin lenses, is used to a considerable extent in this country. One lens projects the picture on the pickup tube inside the camera. The tube is an electronic vacuum tube shaped like a dipper. Inside the pan-shaped part of this tube is located a mosaic screen. The lens projects the picture onto this screen inside the vacuum tube.

The second lens projects the picture on a piece of ground glass. This picture is seen through a hole in the back of the camera. This viewing hole has a projection around it that is shaped to fit the cameraman's face so that no light seeps in as he views the picture.

Both of these lenses are mounted on a single plate in front of the camera. This plate is moved back and forth for focusing. The plate or lens mounting is mechanically connected to a handle which is located at the rear of the camera. As the cameraman looks through the viewing hole at the picture he can adjust these lenses for focus by merely turning the handle. This is necessary in transmitting moving pictures because the actors are often moving. As they move either forward or backward, the camera must be refocused. Quite often the camera is moved to provide certain special effects—this also requires the cameraman to change his focus as the camera is moved. So this viewing screen inside the camera and this focusing system allow for great flexibility.

This camera is also designed so that lenses can be easily changed. There are various kinds of lenses that are used for different types of camera work. The cameraman selects the lens he wants to produce the desired effect.

The focal length of a lens is measured within the camera from the center of the lens system to the plate or film on which the image is projected. This is measured when the camera is focused at infinity. In television work the normal lens has a focal length of about 6 inches. Longer focal length lenses are used to magnify a scene. If it is desirable to take a close-up picture, but with the camera a considerable distance from the action, then a longer focal length lens is used. This is done when television cameras are used at football or baseball games to take close-up action at a considerable distance from the camera. Very long focal length lenses are called telescopic lenses because the lens then operates as a telescope. If the cameraman wants the camera close to the action, but still wants the effect of a long shot, he uses a short focal length lens, often called a wide angle lens. For normal studio work 6- or 12-inch focal length lenses are used. For outdoor sports 12-, 18-inch and sometimes 36-inch lenses are used. The so-called speed of a camera lens is determined by the amount of light that is allowed to pass through the lens to the film or mosaic. If the diameter of the lens is large, then the lens is considered to be fast. To indicate the speed of a given lens, "f" numbers are used. The ordinary box camera usually has an f-11 lens which is fairly slow. With ordinary film in direct sunlight this lens



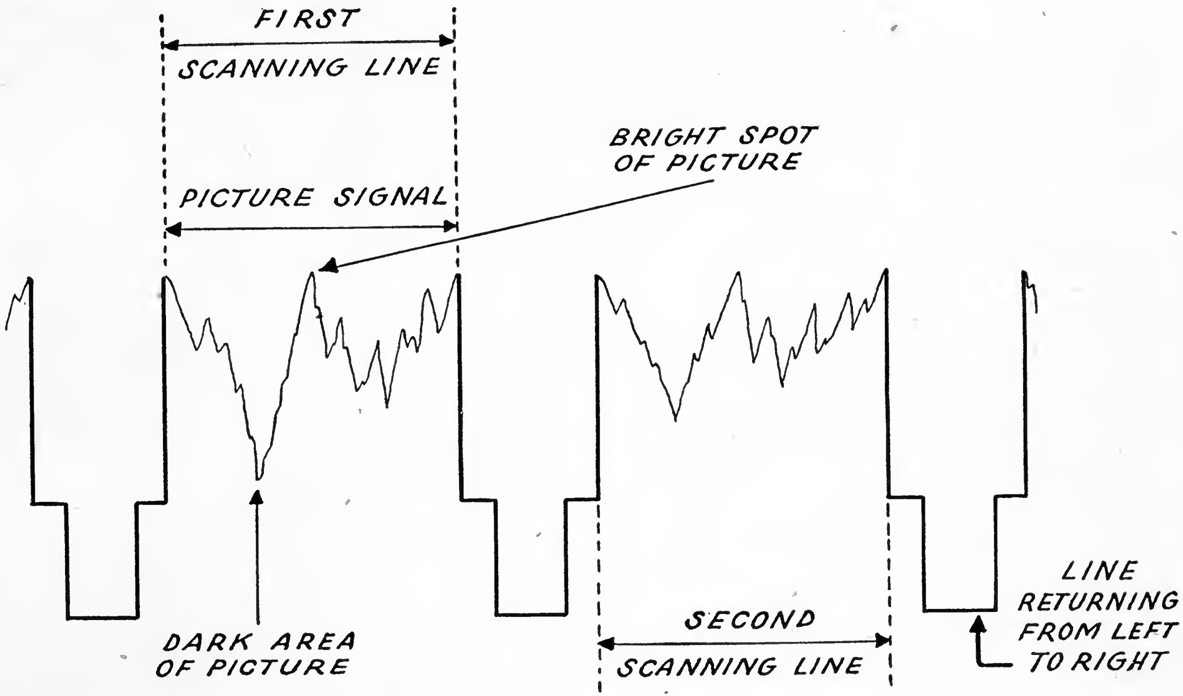
THE EFFECT OF THE LENS OPENING ON THE TELEVISION PICTURE will take a picture with shutter speed of about 1/25th or 1/50th of a second. If you should want to take the same picture in the shade at the same shutter speed you would require a faster lens. You would probably need a lens with a speed of f-5.6 or f-8. The lower the f number the faster the lens.

In television work, quite fast lenses are used—f-2.8 or better. One of the reasons for this is that the studio television camera is not as sensitive to light as still picture or motion picture cameras. Most film is more sensitive to light than is the device used today in a television camera for televising pictures. A more sensitive camera tube has been developed by R.C.A., and is being used at the present time to photograph boxing bouts and other special events where the lighting is inadequate. This tube is called an electron multiplier. Two screens are used inside the tube, an image screen and an electron screen. By transferring this image to the second screen a very weak picture can be amplified.

It is desirable to be able to change the speed of a lens, that is, to be able to make a lens slower than its maximum speed, so cameras are equipped with an Iris diaphragm which can be closed down to a very small opening or opened to the full size of the lens. This Iris diaphragm functions in the same way as the iris of an eye. When the pupil of an eye is small the iris has closed over the pupil to reduce the amount of light that passes through the lens of the eye. You have probably noticed your pupil becomes smaller when you face a strong light. The diaphragm on a television camera lens functions in the same way except that it is not automatic, but is set at the desired opening by hand. On the television camera this adjustable opening is coupled to an indicating system which is marked off in f numbers. As you increase the f numbers you are closing the iris and reducing the light that can pass through the lens. Of course, it also works the other way; as you reduce the f numbers you are increasing the light that passes through the lens.

Cameras are usually marked so that each f number as you go down the scale doubles the light that passes through the lens. At the present time under good studio lighting conditions television pictures are generally shot at f-2.7 or f-3.5. As a rule it is desirable to take a picture at the largest f number which can possibly be used because it increases the focal depth of the camera. In other words, when the camera is focused on an object, other parts of the picture in front of and behind that object are also in focus. This depends on the amount of light available and the sensitivity of the camera. If a more sensitive camera is used, or more light can be thrown on the set, the camera can be set at a higher f number.

This range of distance in which objects are in focus represents the focal depth. Focal depth is increased in two ways. One is by closing the lenses down or, in other words, increasing the f number. When you step a lens down or shoot a picture at the largest f number possible you are increasing



ELECTRONIC SIGNAL PRODUCED BY TELEVISION CAMERA the focal depth. The second way focal depth can be increased is by moving the focus point away from the camera. As you focus on objects further and further away from the camera, the focal depth increases. In close-up shots, such as a head shot with an f-3.5 opening, the depth of focus is only a few inches. When the camera is focused on objects 15 or 20 feet from the camera the focal depth may increase to several feet. The focal depth also varies with the focal length of the lens. To set the f opening on a camera accurately, light meters are used. Meters used by most professional photographers and cameramen operate by means of a photoelectric cell. This cell is sensitive to light and causes a current to flow in the meter. The amount of current that flows depends on the intensity of the light. The meter is usually marked off in f numbers or foot candles. The cameraman can hold this meter up near the object to be photographed and read the correct setting for his lens directly in f numbers. If he wants to step his lens down or use a larger f number than the meter indicates as correct exposure for the picture he must increase the intensity of the light on the picture.

The fundamental principle back of the television camera is transforming a picture image into electrical impulses. This is accomplished by the tube in the television camera. The tube does this electronically. The picture is projected on a screen which is located inside the vacuum tube. The surface of this screen is made up of thousands of minute

Courtesy of C.B.S.

TELEVISION CAMERAS IN OPERATION

particles sensitive to light. These particles are photoelectric cells and the surface is called a mosaic.

As light falls on this mosaic surface the photoelectric cells become electrically charged. The degree of charge is dependent upon the intensity of the light falling on a given area.

As the picture is projected on the mosaic screen by the camera lens system, a picture consisting of electrical particles is produced on this screen inside the tube.

The tube is shaped like a covered pan with a handle. It is made of glass and the screen is located in the round pan-shaped part of the tube. The part of the tube which is shaped like a round handle contains an electron gun. A cathode supplies the electrons in this gun, and other electrical elements form these electrons into a tiny stream. Coils are located around this handle and they are used to control the stream of electrons. By using varying current these coils can be made to move this stream of electrons up and down or sideways. The coils are called deflecting coils because they move this stream of electrons by magnetic deflection.

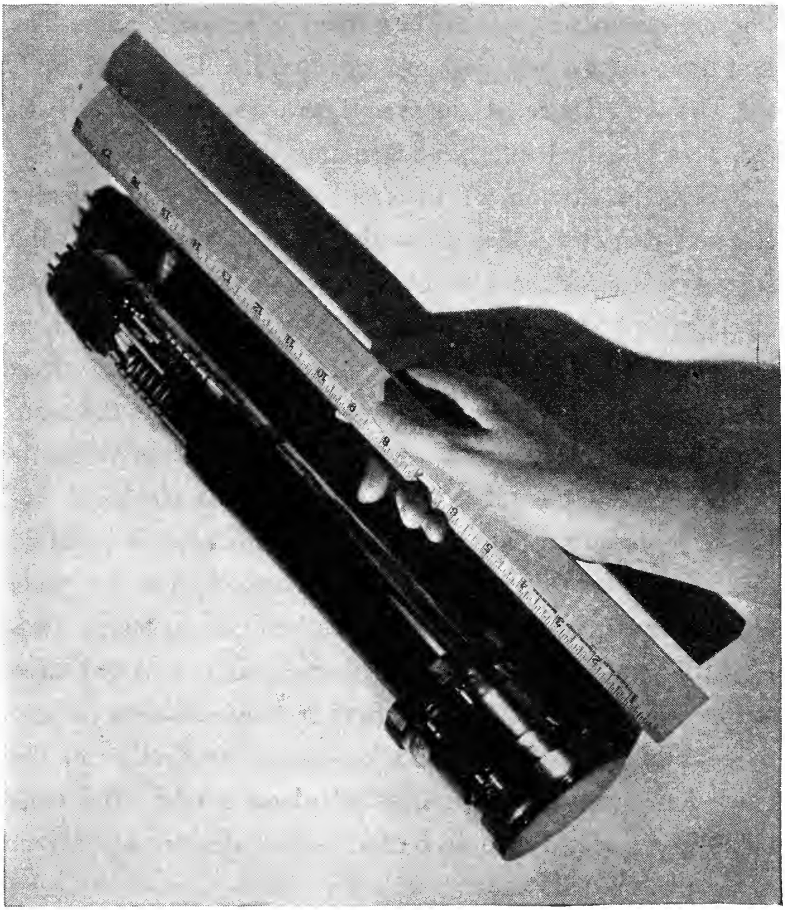
The electron gun is placed in such a position in the tube that the electron stream strikes the photoelectric screen on which the picture has been projected. The electron stream moves back and forth across the screen, gradually traveling from the top of the picture to the bottom. This process is called scanning and one complete operation requires approximately $1/30$th of a second.

The entire picture is not scanned in a single operation. For one complete picture the screen is scanned twice. The first time, all the odd lines are scanned, i.e., lines 1, 3, 5, 7, etc. The second time, all the even lines are scanned, 2, 4, 6, 8, etc. This is called interlaced scanning.

When the stream of electrons strikes the electrically charged particles which form the television picture on the screen, it causes them to be discharged. These discharged electrical particles are picked up by another element in the tube. This element is wired to an amplifier tube so these tiny impulses can be amplified and transmitted. As the scanning process proceeds, a series of electrical impulses is transmitted by the tube. Each one of these electrical impulses represents a part of the picture. This process is called dissecting. Mechanically, you would accomplish the same thing if you cut a newspaper picture into narrow strips starting at the top and working to the bottom. If you pasted these strips end to end you would have a long strip varying in degrees of gray. This would be somewhat similar to the television signal being transmitted along a wire. The various degrees of gray would be the various degrees of current being transmitted.

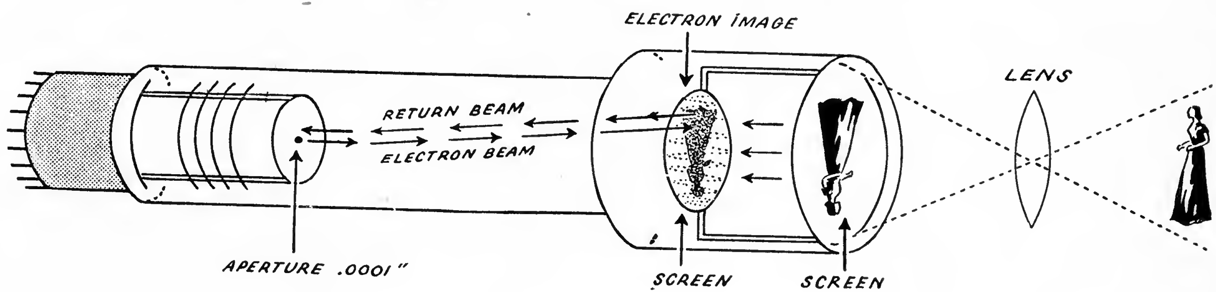
Actually there are slight interruptions in this transmitting process. The scanning is only done in one direction from right to left. The electron stream is cut off when the beam returns from the left side of the screen to the right.

The current which controls this scanning process is vary-

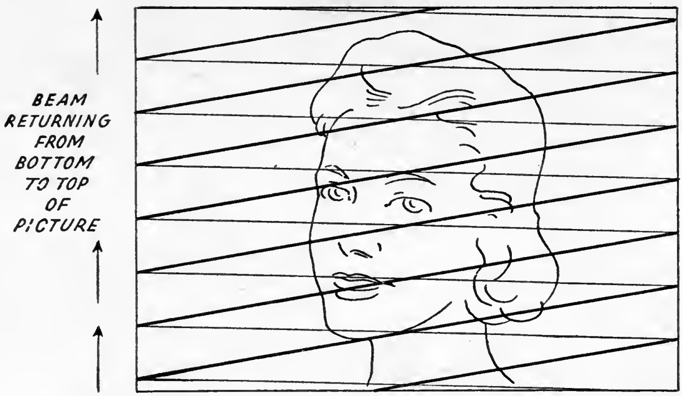


Courtesy of R.C.A.

SUPER-SENSITIVE TELEVISION CAMERA TUBE. THIS TUBE IS KNOWN AS THE R.C.A. IMAGE ORTHICON. THIS TUBE CAN PICK UP PICTURES LIGHTED ONLY BY CANDLELIGHT



NEW TYPE SENSITIVE CAMERA TUBE

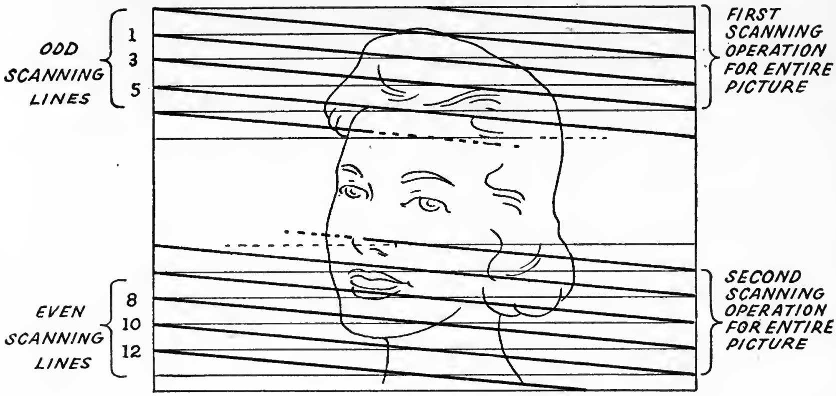


RETURN SCANNING FROM BOTTOM OF PICTURE TO TOP

ing. It is therefore called an alternating current. This alternating current is transmitted along with the picture signal as it is also used by the receiver to reassemble the picture.

The number of scanning lines determines the quality of the picture which can be transmitted. In other words, the more individual particles or lines the picture is broken into the more details are transmitted.

The television camera not only houses the pick-up tube but also the amplifier which amplifies the signal developed by the tube. This is done because the signal developed by the picture-dissecting process is too weak to be transmitted even over wire. In fact, even after amplification a special type of wire has to be used to transmit the signal to the studio control room. Electrical currents which have a high



INTERLAND SCANNING

alternating frequency tend to radiate when they are transmitted over wire. They radiate the same way an antenna system does. To eliminate this radiation, which is a loss of energy, a special type of wire is used. It is really not a wire but a cable consisting of a tubular metal shield with a wire running through the center of the shield. The wire is kept from touching the shield by insulating discs. This type of line is known as a coaxial line and it is used to transmit the television signal from one piece of equipment to the next. It is used between the cameras and control room equipment, also between the control room and the transmitting station. This conserves the energy which would otherwise be lost by radiation.

Chapter Eight

TELEVISION TRANSMITTER

THE main function of any transmitter, whether it be broadcasting or television, is to generate a powerful signal which can be dissipated into space by an antenna system. This signal travels through the ether to the receiving antenna where it is picked up again and transferred back into sound, or into picture and sound in the case of television. The radio energy thus sent is fluctuating like an alternating current (A.C.) and is transmitted in the form of waves. If you visualize it as ripples of electrical energy traveling in all directions through the air from an antenna system, you have the basic conception of how it functions. This energy is called a carrier wave, as it carries the program picture or sound to your receiver.

The number of waves or oscillations that occur per second determine the frequency of the carrier wave. Most homes in large cities use alternating current. The frequency of this current is usually 50 or 60 oscillations per second. For carrier waves, currents of much higher frequency are used. For the television carrier wave, oscillations or cycles above 100,000,000 per second are used. Any frequency of above 1,000,000 cycles per second is called a megacycle. So black and white television requires frequencies above and below 100 megacycles per second for carrier waves.

Each transmitting station in any locality operates on a different carrier wave frequency. These frequencies are assigned by the Federal Communications Commission because two stations operating on the same frequency in the same locality would interfere with each other.

The main function of the transmitting station is to generate currents at these frequencies and to amplify them. Currents of this type are radiated by an antenna system. The design of the antenna is dependent upon the frequency of the energy being radiated. So the television transmitter generates a current of a certain frequency which must be accurately controlled. First, this frequency is generated and then the picture impulses coming from the television camera are combined with the carrier wave.

To generate a current of a certain frequency, an electronic vacuum tube is used similar to the amplifier tube previously described. The grid of this tube is called the input and the plate, the output. By connecting these by means of an electrical circuit containing other elements, oscillation of currents can be created. These oscillations can be controlled by the use of a quartz crystal in the circuit. This device is known as a Crystal Oscillator.

When current is properly applied to the crystal it will vibrate mechanically. The frequency with which it vibrates is determined by the thickness of the crystal and the way it is cut. The crystal is cut to vibrate at the carrier wave frequency. It then acts as a control in the oscillator circuit of the transmitter. The signal which is developed in this manner is the carrier wave and when it is amplified it can be applied to an antenna of the proper design and radiated into space. It is of little use, however, unless it is transmitting either sound or picture.

After the signal is generated by the oscillator circuit of the transmitter, it is amplified. It is then ready to be combined with the picture or sound signal coming from the studio. In other words, the picture impulses which are developed by the television camera are combined with signals generated by the transmitter. The part of the transmitter which accomplishes this is called the modulator section containing high-powered vacuum tubes. The picture impulses are actually combined with the carrier wave inside a vacuum tube. By applying one signal to the grid of the tube and the other signal to the plate, the two signals can be combined. Thus the picture impulses are impressed upon the carrier wave and in this manner they can be transmitted to your home.

As a signal of considerable strength must be transmitted in order for you to have good reception, very powerful electronic tubes must be used in the transmitter. With tubes of this type, a considerable amount of energy is lost in heat. In fact, so much heat is generated by the tube that the elements would melt if they were not artificially cooled. This is done in either of two ways. In one case, a stream of cool air is used to keep the tube at its proper temperature. The other method is to circulate cold water around the tube.

When water is used, it does not touch the glass portions of the tube. The working elements of the tube—the grid and filament—are inside a copper tube. The copper tube acts as the plate. A glass envelope is attached to this copper tube. It is through this glass portion of the tube that the electrical connections are made. Thus the upper part of the tube is glass and the lower part is in the form of a copper tube. When the tube is in operation the copper part is placed in a water jacket, and water is circulated through the jacket so the heat is carried off. Distilled water is used as it is a poor conductor of electricity. If this were not done, current would flow back through the water-circulating system. Usually a coil of porcelain pipe is also used in the water-circulating system for insulating.

When the tubes are cooled by air, cooling fins take the place of the water jacket. These fins are attached to a ring which fits closely to the copper tube. A stream of cool air is forced through these cooling fins. This is done by a large fan and duct connections to the base of each tube.

In this manner the heat is carried off by the stream of cool air.

These tubes, crystals and other elements of the transmitter are housed inside a cabinet, as a rule, or several cabinets in the case of a large transmitter. Usually, meters which are used to check the transmitter operation are mounted on the front of the transmitter housing. These meters are used by engineers to check various currents that are applied to the tubes.

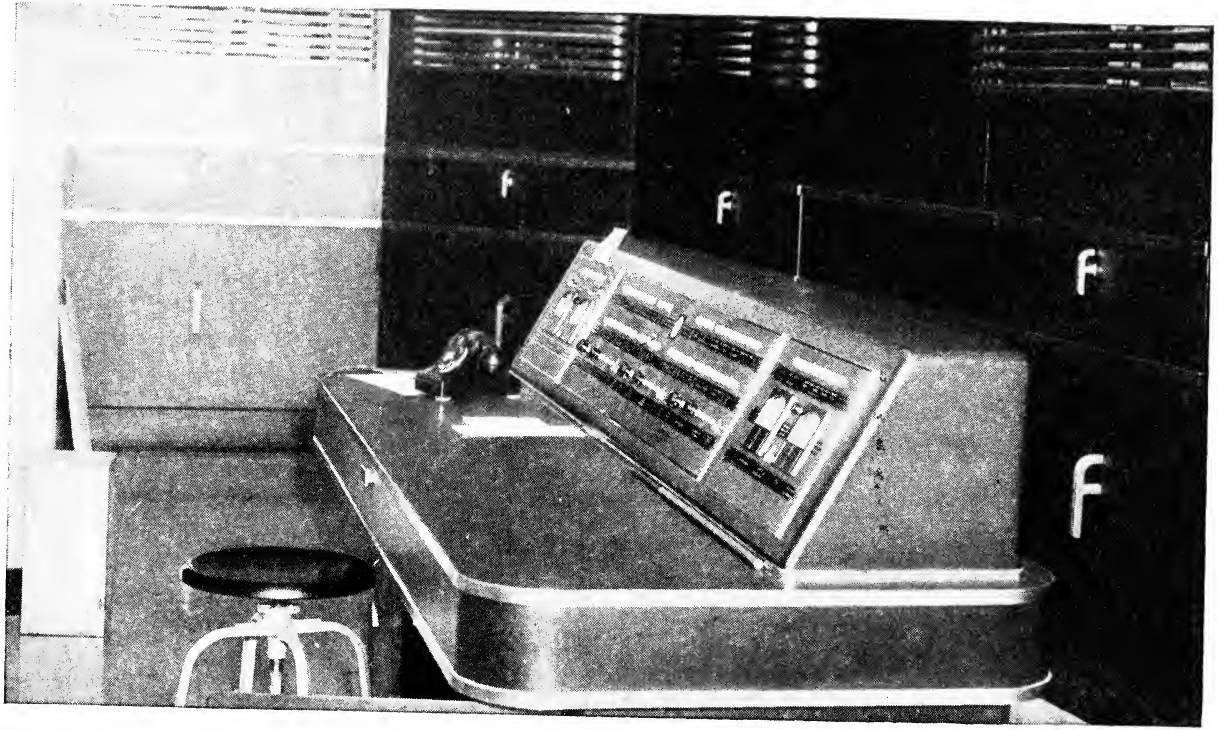
In a great many cases the transmitter is arranged so that the equipment panels form one wall of the transmitting room, controls and meters being mounted on the front panel. Usually there are doors in this panel which can be opened so that the equipment can be inspected. This cannot be done while the equipment is in operation because voltages as high as 10,000 to 20,000 are used in the transmitter circuits. In order to protect the operating engineers, interlock switches are used on the transmitter door. These switches automatically cut the transmitter off as soon as a door is opened, and also eliminate the possibility of the transmitter being turned on while an engineer is working on the equipment.

In front of these panels the engineer's control desk is located. On this desk are the various switches for turning on the transmitter. The transmitter has to be turned on in steps so as not to burn out the various transmitting tubes. There are also indicating lights on the desk which show what parts of the transmitter are in operation.

A television receiving tube is used to check the picture, usually both before and after transmission. One tube is connected to the incoming line from the television studio and the other to the output of the transmitter. In some cases it is picked up by a regular receiver. In this manner the engineer can view the picture before and after transmission. By comparing these pictures he can tell if any defects have been caused by the transmitter failing to function properly.

One of the main functions of an engineer supervising the operation of a television transmitter is to locate trouble. The transmitter contains hundreds of radio parts in the electrical circuits besides the many high-powered vacuum tubes. The engineer's job is to detect trouble as soon as it develops. He must not only detect the trouble, but he must locate it and remove it as soon as possible. In the case of television it is a lot more difficult than in regular broadcast transmitters. The engineer not only has the sound to listen to and check, but he must check the picture for defects caused by breakdowns in the various parts of the equipment. Under most circumstances an experienced engineer can locate the trouble and remove it almost immediately. Sometimes just by listening to the sound or looking at the picture he can tell what piece of equipment is not functioning correctly. The ability to do this comes mainly from experience with the equipment.

However, the equipment is designed so that most difficulties can be located easily. The transmitter is broken down into many sections. Each section is equipped with meters and indicating lights to show how the equipment is func-

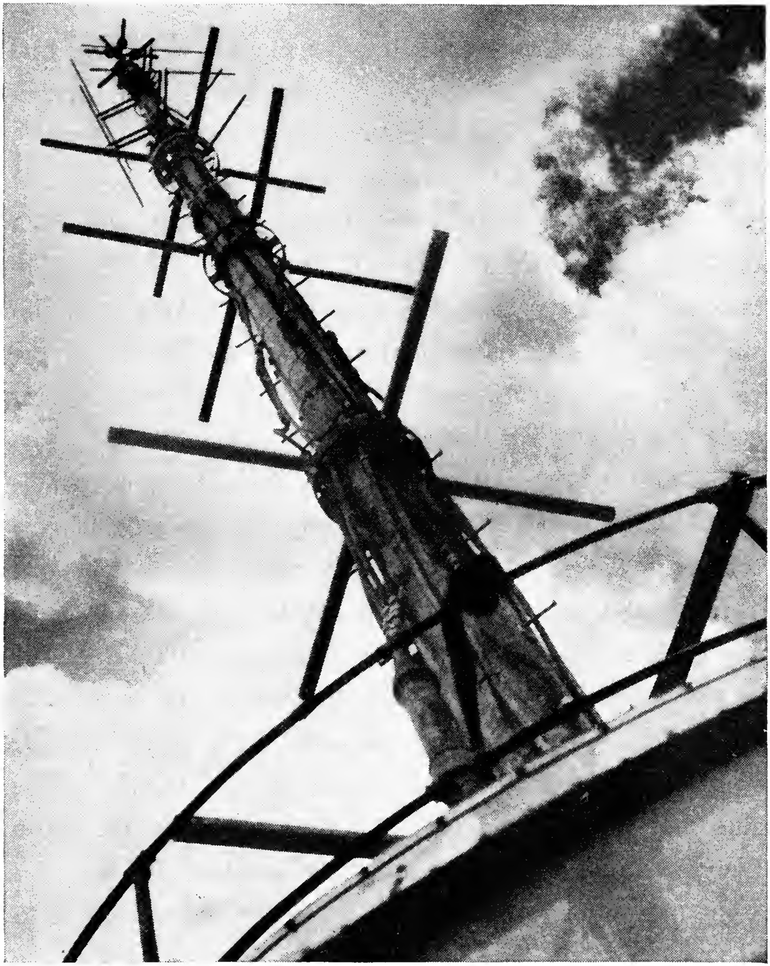


Courtesy of C.B.S.

TRANSMITTER CONTROL DESK FOR BLACK AND WHITE TELEVISION tioning. The engineers check these meters periodically and keep a complete running record as to how the equipment is functioning. This log helps new men coming on duty to check the transmitter operation and to locate trouble. If they see that a certain piece of equipment has not been functioning properly that day it may help them later to trace a breakdown. The log also helps the men to maintain the equipment. After the transmitter is shut off for the night, the equipment which has not been functioning correctly is inspected for defects.

Lost air-time means lost income, as commercial programs can ask for a credit if the station goes off the air during a commercial program. Usually the transmitter is put into operation an hour or more before air-time. The carrier wave may even be transmitted without the program. This allows the engineers time to check their equipment and make sure it is operating properly. Just prior to the time the regular program is transmitted, a test pattern is put on the air. This affords an over-all check of all the equipment from the studio television camera to the transmitting antenna system.

The test patterns are made on white cardboard with vertical and horizontal tapering black lines. Incorporated in the design are circles and partial circles. The call letters of the station also appear in the design. The test pattern is placed before the camera in the studio. The picture is then checked in the control room. By examining the various lines, it is possible to tell if there are any defects in transmission be-



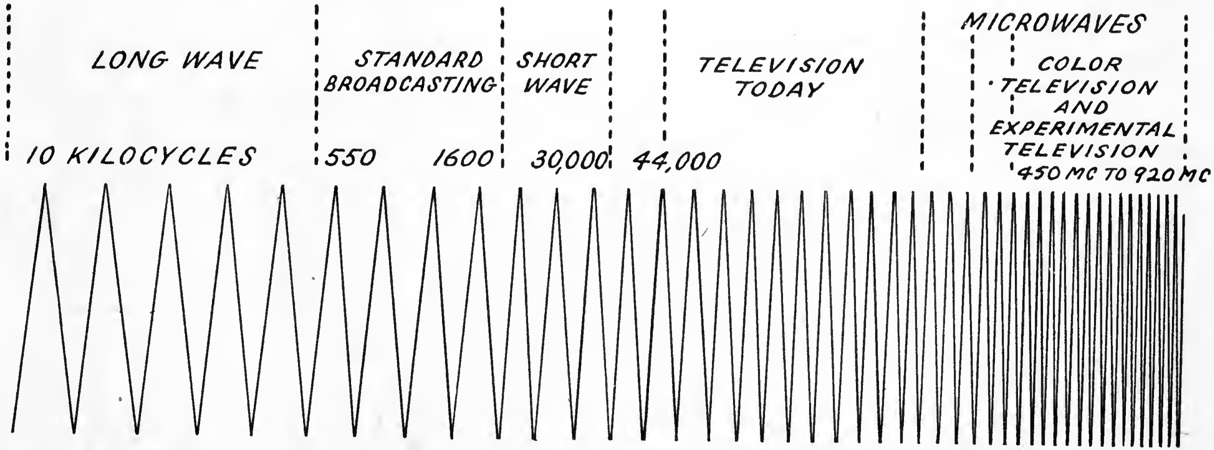
Courtesy of N.B.C.

N.B.C. TELEVISION ANTENNA ATOP THE EMPIRE STATE BUILDING, NEW YORK. THIS ANTENNA BEAMS THE TELEVISION PICTURES OF STATION WNBT TO AUDIENCES IN AND AROUND NEW YORK CITY. LOWEST FOUR SETS OF CROSSBARS ARE FOR TELEVISION, NEXT TWO FOR F.M., TOP ANTENNA IS FOR HIGH-FREQUENCY TELEVISION TESTS tween the camera and the control room.

The engineers at the transmitting station also check this pattern on their receiving tubes. If they detect defects they can tell at what points the trouble is occurring. If the pattern has changed between the studio control room and the transmitting station then they know there is trouble with the line between these points. By checking test patterns with a receiver tube at several points the equipment causing trouble can be found. After this the call letters of the station are announced and the television program goes on the air.

Prior to the war all television stations used two transmitters—one for picture and one for sound, the sound being sent over a separate line to the transmitting station. Each transmitter generated a separate carrier wave, the sound coupled to one and the picture to the other. Separate antennas were also used for picture and sound. These transmitters are still in use today, but since the war a new system has been developed which requires only a single transmitter for both sound and picture. The television sound on picture system will be described separately.

After the picture signal has been combined with the carrier wave generated by the transmitter, it is sent over a coaxial line to the antenna system. The antenna system radiates this energy into space. In order to do this the antenna system must be of a certain design to operate efficiently. For radio broadcasting very tall antennas are used, whereas television uses quite small antennas. The fact that tall build-



CARRIER WAVE FREQUENCIES FOR BROADCASTING AND TELEVISION ings are quite often used for television transmitter points does not affect the size of the antennas. The size and design of the antenna system are dependent upon the carrier wave, being determined by the frequency or the number of times per second each wave is generated.

Quite often the word *wave length* is used instead of *frequency* to describe a carrier wave. The wave length is the distance a single wave travels in air while it is being generated. Radio waves travel in space at the rate of 186,000 miles a second. If it takes one second to generate a wave (the frequency being one cycle per second) then the wave length would be 186,000 miles. Naturally, this works out so that the higher the frequency the shorter the wave length. As television uses very high frequencies for the carrier wave, the wave length is quite short. These carrier waves have a wave length of about 5 to 14 feet.

A piano string vibrates at a certain frequency, depending upon its length. Antenna systems also radiate energy dependent upon the frequency or wave length of the signal. An antenna system radiates most efficiently when it is approximately one, ½ or ¼ wave length long. If the length of a carrier wave is eight feet then the antenna system should be eight feet, four feet or two feet. A small copper rod cut to the proper size will act as an antenna system.

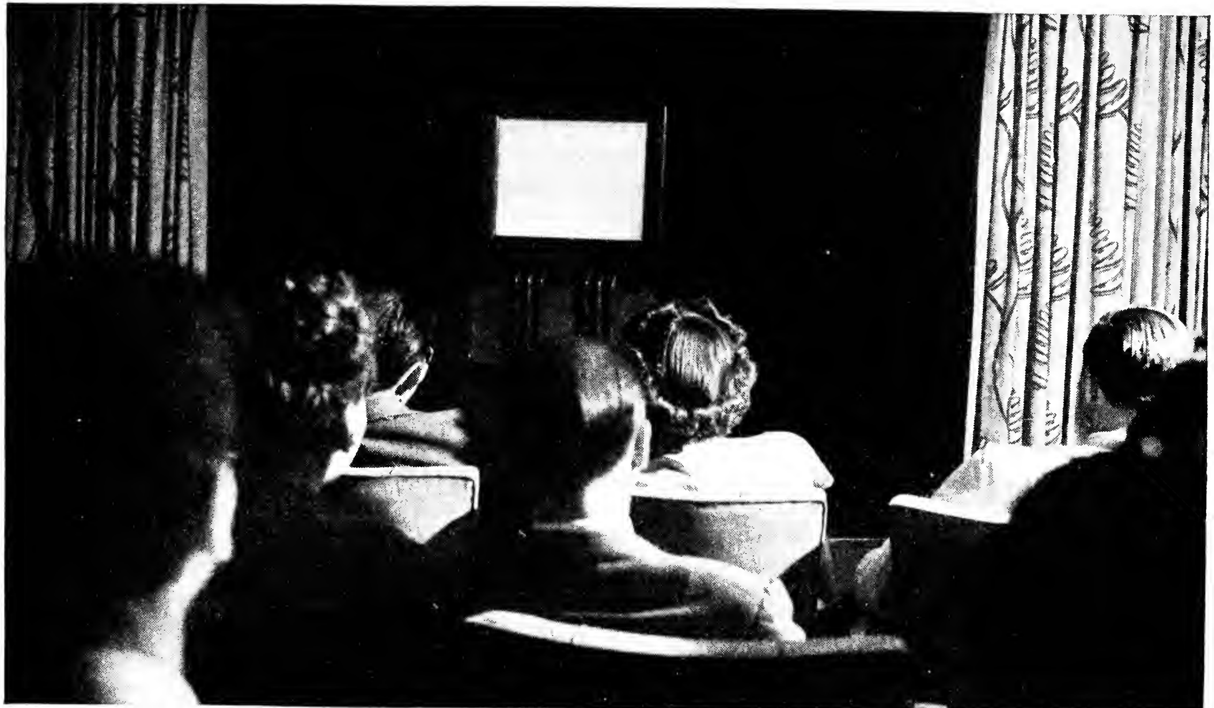
In order to make an antenna system more efficient, it is usually designed so that it is directional. The energy which would normally be radiated towards the sky is radiated in a path horizontal to the earth's surface. To accomplish this, several antennas are stacked one above the other. These antennas vary considerably in design, but all operate as directional antennas. This blankets the area within a sixty-mile radius of the transmitting station with radio energy. Every properly designed television receiving antenna in this area picks up part of this energy. The receiver transforms the energy back into live motion pictures. So each home equipped with a receiver can see the action being telecast.

Chapter Nine

TELEVISION RECEIVER

TODAY there are several types of black and white television receivers available commercially. They all operate on the same fundamental principle—that is, they receive a complicated television signal, amplify this signal and utilize it to produce the picture on the receiving set screen. The electrical circuits in the television receiver which produce the resulting picture are quite complicated, but the basic principles of these circuits are not too difficult to understand. The picture is reassembled by an electronic vacuum tube which reverses the process of the television camera tube.

As in radio, the first operation of a receiver is to select one of the programs which is being picked up by the antenna system. It must be remembered that the receiving antenna picks up many carrier waves. In the case of television, each carrier wave represents a program. As we have said earlier,



Courtesy of N.B.C.

SPECIAL VIEWING ROOM IN N.B.C. STUDIO, NEW YORK. R.C.A. PROJECTION TYPE RECEIVER there are at present two different types of television transmission. One system uses two carrier waves—one for picture and one for sound. The newer system uses a single carrier wave for both picture and sound. In either case, the receiver must select the carrier wave or waves which are bringing in the program you desire.

This is done by a special circuit which acts as a radio frequency selector. A coil of wire in a radio circuit is known as an inductance. The number of turns in the coil and the size of the wire determine the value of the inductance. A device known as a condenser, which can be a series of metal plates properly spaced, provides what is known as capacitance in a radio circuit. When these devices are properly arranged in an electronic circuit they produce what is known as a "tuned circuit." That is, the circuit will pass currents of a certain frequency range but will not pass currents beyond a certain range. This circuit acts as a filter, cutting out the undesirable signals which do not fall into the frequency range for which the circuit is designed. If a transmitting station is televising on a carrier wave frequency of 490 megacycles and that is the frequency for which the receiving circuit is designed, this frequency will pass through the circuit. If another station is televising at the same time on a frequency of 100 megacycles, the circuit will eliminate that carrier wave.

This process is similar to that by which a musical stringed instrument produces sounds of certain frequencies, depending on the size and length of the string in the instrument. The piano strings are tuned to produce sounds of certain frequencies. The electronic circuit is tuned to pass currents of a certain frequency range.

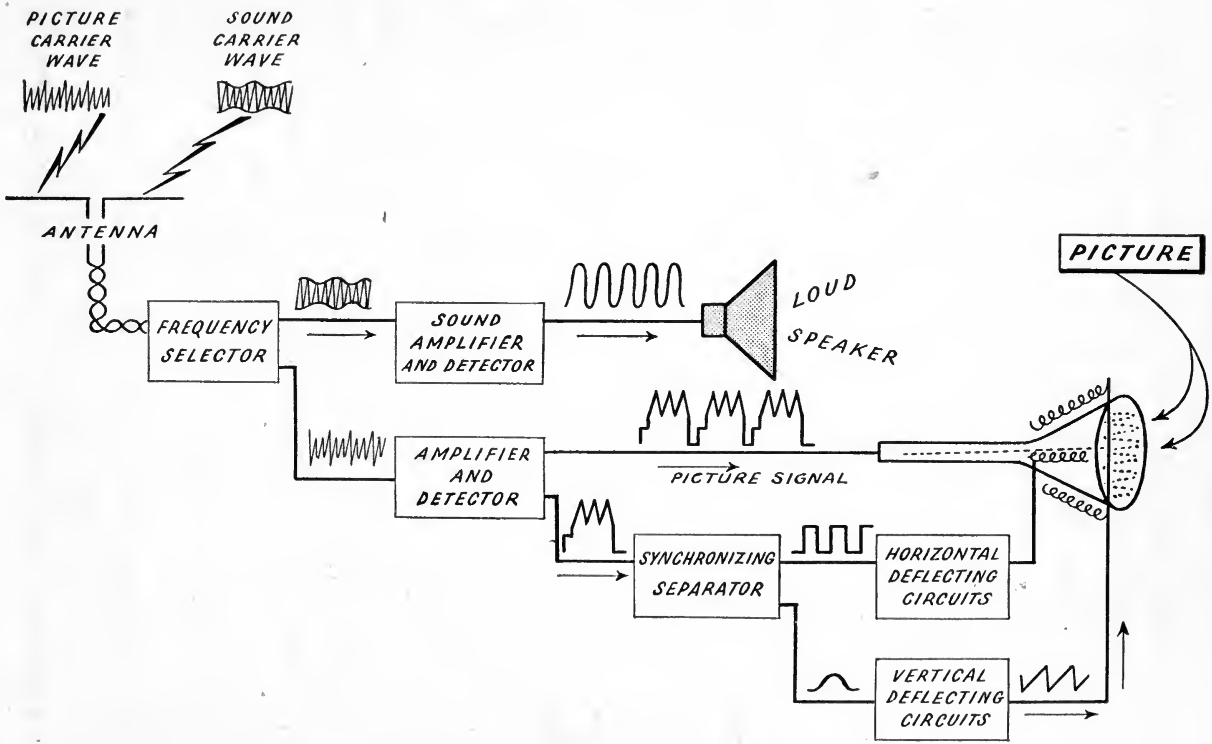
Several circuits of this type are used in the television receiver to select the carrier wave of the station you desire to receive. Each circuit is tuned to a different frequency range, there being one tuned circuit for the particular frequency on which each television station, such as Columbia Broadcasting System, National Broadcasting Company, and Dumont, telecasts. These circuits are cut in or out by means of a switch. This switch usually appears on your receiver as a series of push buttons, each button being marked with the call letters of the particular station for which the circuit is tuned. When you push down one of these buttons to select a station you are actually tuning your set to receive the carrier wave of that particular station. This circuit selects both the sound and picture carrier waves, or the single carrier wave with picture and sound combined.

The second function of your receiver is to amplify the signal received, as it is too weak at that point to be of any value. To amplify signals over a broad band of frequencies is quite difficult. For this reason, a special circuit called a superheterodyne circuit is used to a great extent in receiver design. This circuit changes the carrier wave frequency to a single frequency which can be easily amplified. It has been discovered that when two frequencies are combined they produce a third frequency. This third frequency is the difference between the two frequencies which have been superimposed, one upon the other. If the carrier wave frequency to which you are tuned is 70 M.C., the superheterodyne circuit produces a frequency of 60 M.C., and the third frequency produced will be 10 M.C. This third frequency is the one which will be amplified. The tuning of this superheterodyne circuit is done by the same switch which selects or tunes in the carrier wave. The figures given are arbitrary and are only to illustrate how the superheterodyne circuit functions. The third frequency produced by this method is always the same and hence is easily amplified.

This circuit is also called an oscillator circuit as it produces current which oscillates at certain frequencies. It is accomplished by a vacuum tube which operates in just the opposite way to a rectifier tube which changes alternating currents into direct currents. An oscillator circuit changes direct current into oscillations of certain frequencies.

The third frequency produced by your receiver still contains all the impulses that the original carrier wave contained. These impulses are necessary to produce the television picture—in other words, they are the impulses that were produced by the television camera and microphone in the studio.

The next section of your receiver separates the picture carrier wave from the sound carrier wave. This is done by two amplifiers. One amplifier is designed to filter out the



BLOCK DIAGRAM OF TELEVISION

picture signal and pass the sound signal. This is called the audio amplifier. The other amplifier does just the opposite —it filters out sound and allows the picture signal to be amplified. This is called the picture or video amplifier.

Forgetting about the sound or audio signal for a minute, we will follow the picture signal and see how it is utilized to reproduce the picture on the television screen.

The first stage in picture electrical process eliminates the picture carrier wave which was utilized to carry the various picture impulses to your receiver, leaving only the impulses or signal necessary to produce the television picture. This remaining signal is really a combination of three synchronizing signals—horizontal scanning, vertical scanning and variations of gray, black and white which make up the television picture. The next thing which is done by the receiver through the use of electronic circuits is to split this synchronizing signal into two separate signals. One of these signals becomes a synchronizing scanning signal and the other a picture signal. The scanning signal is then further divided into two more signals—one being vertical scanning and the other horizontal scanning.

These three synchronizing signals are fed by means of wires to three elements in the picture-receiving tube. Both the projection type of tube which is used to project the picture on a screen, and the direct-viewing type of tube work on the same fundamental principle.

These three signals are used to control the electrons inside the picture-receiving tube. This tube produces a tiny stream of electrons which, upon striking the fluorescent screen, creates a bright spot visible to the eye. The three signals are used to control this stream of electrons. One signal controls the quantity of electrons, thus controlling the intensity of the spot produced on the screen. This signal is called the picture signal because it controls all the light and dark areas of the picture. The second signal is used to deflect this stream of electrons in a vertical plane, causing the electron stream to move up and down. The third signal causes the stream of electrons to move back and forth on a horizontal plane.

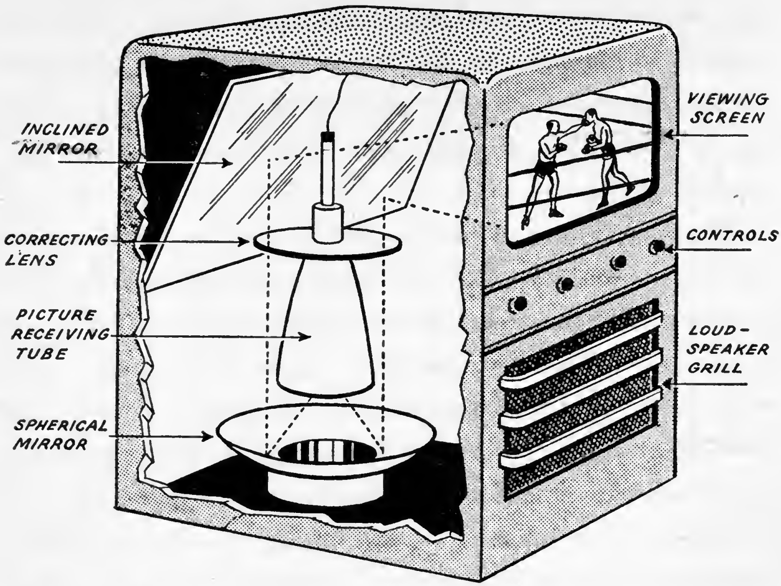
This deflection of the electronic beam is accomplished by applying the scanning signals either to a set of metal plates inside the vacuum tube or to coils of wire which are located close to the throat of the tube. They are known as horizontal or vertical deflecting plates or coils.

When the proper current or wave form is applied to these deflecting devices it causes the electronic stream to move back and forth at a very rapid pace. It also causes the stream to move at a somewhat slower speed from the top to the bottom of the screen. These two deflecting signals, which are part of the signal picked up by your receiver, produce what is known as scanning. This scanning process is so rapid that the eye cannot detect it. The bright spot produced by the stream of electrons striking the fluorescent screen travels back and forth across the screen, producing a series of lines as it moves toward the bottom of the screen. This scanning process is identical to the process used in the television camera tube to dissect the picture. In fact, it is the same signal which is sent to your home by means of the television transmitter.

If this spot which scans the screen did not vary in intensity, the screen would appear as a white rectangle of light. The spot is varied, however, by the picture signal as each line is produced. The dark and light areas of the picture are reproduced by the varying intensity of this spot. The scanning reproduces the picture line by line. Each scanning operation takes less than one-sixtieth of a second.

Actually two scanning operations are used to complete one picture, the process known as interlaced scanning. First the electronic beam scans lines 1, 3, 5, 7, etc., and this is called a field. The second scanning operation covers lines 2, 4, 6, 8, etc. This is done to eliminate flicker. Two fields are called one frame, which is one complete picture.

The sound or audio end of the television receiver is quite simple in comparison to the video circuits. After the sound has been separated from the picture signal the carrier wave is eliminated. This is done by a vacuum tube circuit which operates as a rectifier. It rectifies or cancels out the carrier wave, leaving the signal which was originally produced by the microphone in the studio. This signal is then amplified and fed to a loud-speaker which changes the signal back into sound waves.

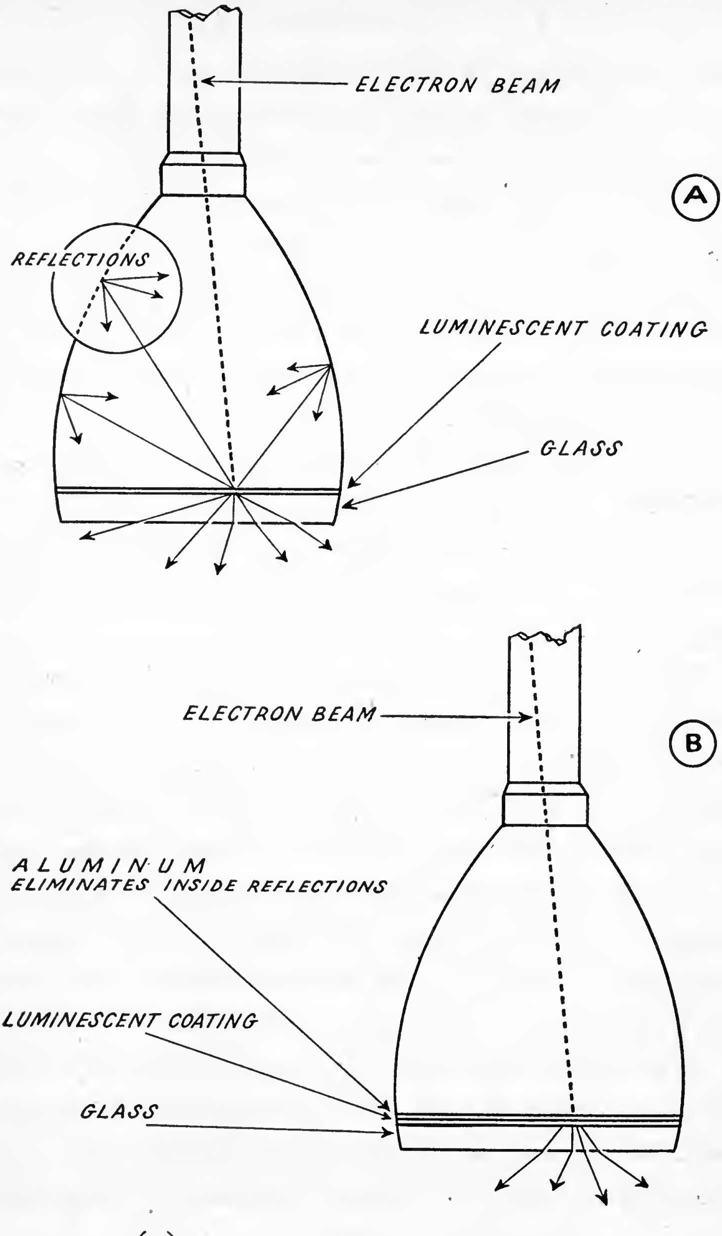


BLACK AND WHITE PROJECTION TYPE RECEIVER

There is one major difference between black and white and colored television in the method of producing the picture on the receiving screen. In colored television the picture is produced on a fluorescent screen which is located inside a funnel-shaped tube. The color is added by means of a rotative color filter which is placed in front of this screen. In black and white receivers, the tube is concealed inside the receiving set cabinet and viewed through a rectangular hole which exposes the end of the tube where the picture appears. This opening serves as a screen on which the television picture is produced. On some receivers the screen appears in the top of the cabinet and it is viewed by means of a mirror which is attached to the lid of the cabinet. These types are known as direct-viewing receivers.

The latest type of receiver is a projection type. Projection-type television receivers have a definite advantage over the direct-viewing type because a much larger viewing screen can be used. This type of receiver uses a small type of high intensity receiving tube. The large end of the tube is approximately 5 inches in diameter. The tube is designed for use with voltages as high as 20,000 to 30,000. It operates on the same fundamental principle as the larger direct-viewing receiving tube, but the small tube produces a very brilliant picture which can be projected by means of an optical system on a large viewing screen.

The tube is mounted facing the bottom of the receiver cabinet. Located in the bottom of the cabinet is a spherical mirror. This mirror has a hole in the center of it so the image on the tube is not reflected back into the screen on the projection tube. The mirror is so shaped that the image is reflected back towards the top of the cabinet, passing around the projection tube. A molded transparent plastic lens located between the top and the bottom of the cabinet brings the picture together again so the hole in the mirror is not seen when the picture is projected on the screen. After the image passes through this lens it strikes an inclined flat mirror located in the top of the cabinet. This mirror projects the picture on a 16 x 21″ translucent viewing screen



(A) OLD TYPE RECEIVING TUBE
(B) NEW TYPE RECEIVING TUBE

located in the front of the cabinet. The picture is projected on the back side of the screen, directly opposite in procedure to the common practice in motion pictures of projecting the picture on the front or viewing side of the screen. This system provides clear pictures with considerable detail so that several people may view the program without sitting too close to the screen. The spherical mirror and correcting lens can also be used to project the picture directly onto a wall. In this case the mirror, tube and lens will be mounted in a horizontal position. R.C.A. has designed larger units mounted in a horizontal position for projecting the picture on standard motion picture screens for use in theaters.

Another feature of this receiver is an automatic frequency control which eliminates stray noise impulses caused by various types of interference. Noise impulses throw the scanning beam in the receiver out of synchronization. This causes picture distortion, as parts of the picture may be cut out or appear in the wrong location.

Television receivers may have several picture controls, some of which may be left in a fixed position or may be automatic. One of these controls is used to adjust the brightness. Another changes the contrast between the dark and light areas of the picture. The focus control adjusts the picture for sharpness. The horizontal control moves the picture from one side to the other and is used to center the picture in a horizontal plane. The vertical control does the same thing in a vertical plane. The width control controls the width of the picture.

The tendency in receivers is to have most of these controls pre-set, the only adjustments made by the viewer being the brightness control and the contrast control. Generally, if a television set has been installed properly it is only necessary to tune the set to the proper station and adjust the brightness and contrast control.

Chapter Ten

TELEVISION COAST TO COAST

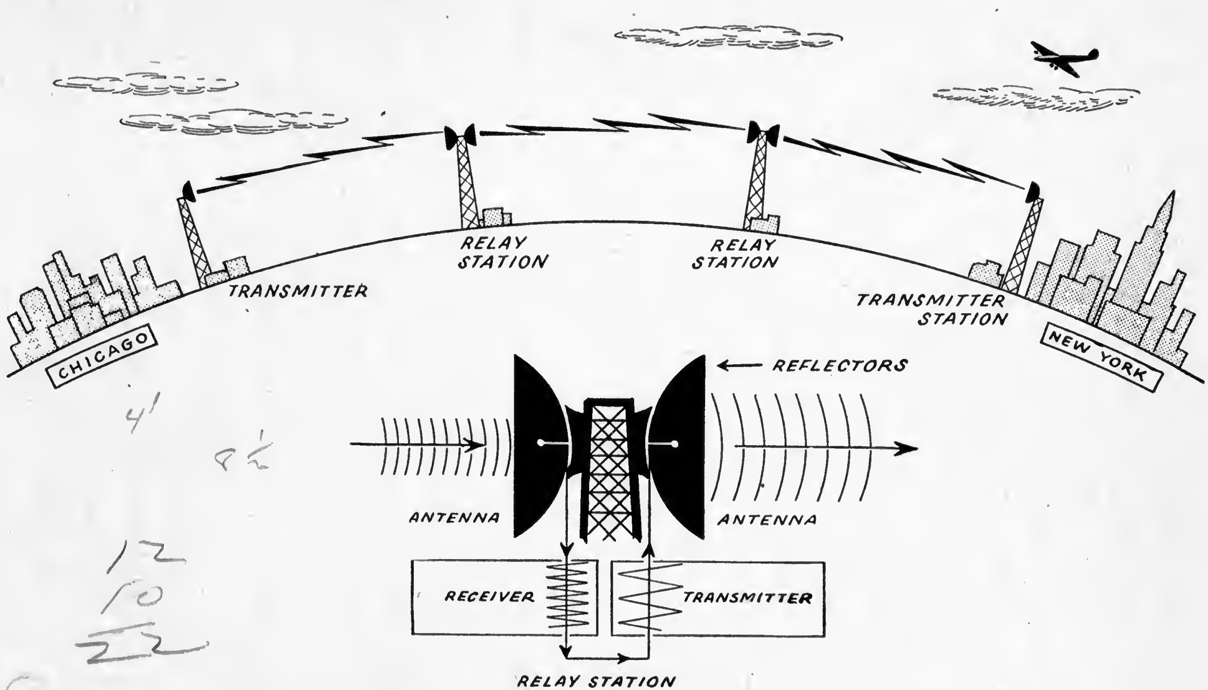
THE necessity for a television system similar to a radio network broadcasting has long been felt. Without a system of this type, television will not be commercially sound, because television, like radio, will have to rely on advertising for its revenue. The amount that an advertiser pays is always dependent upon the number of people the program reaches. By transmitting the same program over a number of stations all over the country, millions of people can be reached. As advertisers will pay a high price for this type of coverage more money can be spent on the programs. Hence, the better programs are usually transmitted over a network of stations. In radio, this is done by sending the program over special telephone lines to various cities throughout the country. Very popular programs are broadcast from coast to coast. The program is carried from a transmitting station in one city to transmitting stations in other cities by the use of telephone lines. This is called network broadcasting.

Television will require a similar system. Unfortunately, television programs cannot be transmitted over special telephone lines because a much more complicated signal is used to transmit the television picture. Actually it is the frequency of the signal which determines whether it can be transmitted over telephone lines or not. As we have mentioned, very high frequencies are used to transmit the television picture. These high frequencies cannot be sent over telephone lines unless a coaxial cable is used. These coaxial cables have been installed between some cities. One of these systems is in use at the present time between New York and Schenectady. It is a relay system in which the program is picked up by a receiver and retransmitted. The General Electric Company television transmitting station (WRGB) in Schenectady, New York, uses a relay station to receive television programs originating in New York. The relay station is located 129 air miles from New York on the peak of the Helderberg Mountains.

This point is high enough to be within line of sight of the television transmitting stations in New York. Normally, New York stations can only transmit about 60 miles, as the short waves used for transmission travel in a straight line. However, if the receiving antenna is high enough, greater distances can be accomplished. This is the case with the General Electric relay station W2XI, located on a mountain top which receives television programs coming from New York and retransmits them to Schenectady. The main station (WRGB) in Schenectady picks up the program coming from the relay station and retransmits. More and more of these relay stations are being installed which will allow programs to be transmitted from city to city.

Relay stations operate on low power as a special type of antenna system is used. The antenna system is directional —that is, it transmits all the energy in a single direction. There are many different types of antennas used to accomplish the directional effect. One of the common types has a curved reflector behind the antenna to direct the waves, thus operating on the principle of a reflector behind a searchlight. This concentrates the television wave in the form of a beam and directs it toward the receiving station. Less transmitting power is required because the energy is concentrated in this form. A relay station may operate on 25 watts of power whereas main television transmitters may use 500, 1,000 watts or more for general coverage, because the main transmitting station has to transmit the signal in all directions.

Applications have been filed with the Federal Communications Commission for permission to establish a skytop relay system on the West Coast. Among the applicants is the Raytheon Manufacturing Company. These stations would be located on mountain peaks and programs would be transmitted from one mountain top to the next, traveling between



TELEVISION RELAY TRANSMISSION

all the major cities on the West Coast. The mountains range in height from 3,000 to 15,000 feet. The system would include stations on Mt. Whitney (14,496 feet), Grays Peak (14,341 feet), Granite Peak (12,850 feet), Mt. Shasta (14,162 feet), and many others. The network would cover the states of Washington, Montana, Oregon, Idaho, Wyoming, Colorado, Utah, Nevada, California, Arizona and New Mexico. The stations would operate on micro-waves, ultra short waves, with frequencies as high as 26,000 megacycles. However, the initial tests will be made on frequencies from 30 megacycles to 26,000.

The plans are to extend the system from coast to coast, covering such cities as Boston, New York, Toledo, Washington, Chicago, Kansas City, Houston and many others. This will establish a means of televising programs simultaneously from all the major cities in the United States. You will be able to see sporting events as they happen in any large city in the country. You might be 3,000 miles away from the event and still see and hear all that goes on. For millions of people who are unable to travel it will be educational and amusing. Sports, drama and other types of entertainment will be telecast in this manner. This system is also designed to carry colored television programs, as colored television transmitters are being installed in the larger cities.

Operators are not required for these relay stations. They may be serviced once a month or once in three or six months. The stations can be designed to automatically switch equip-

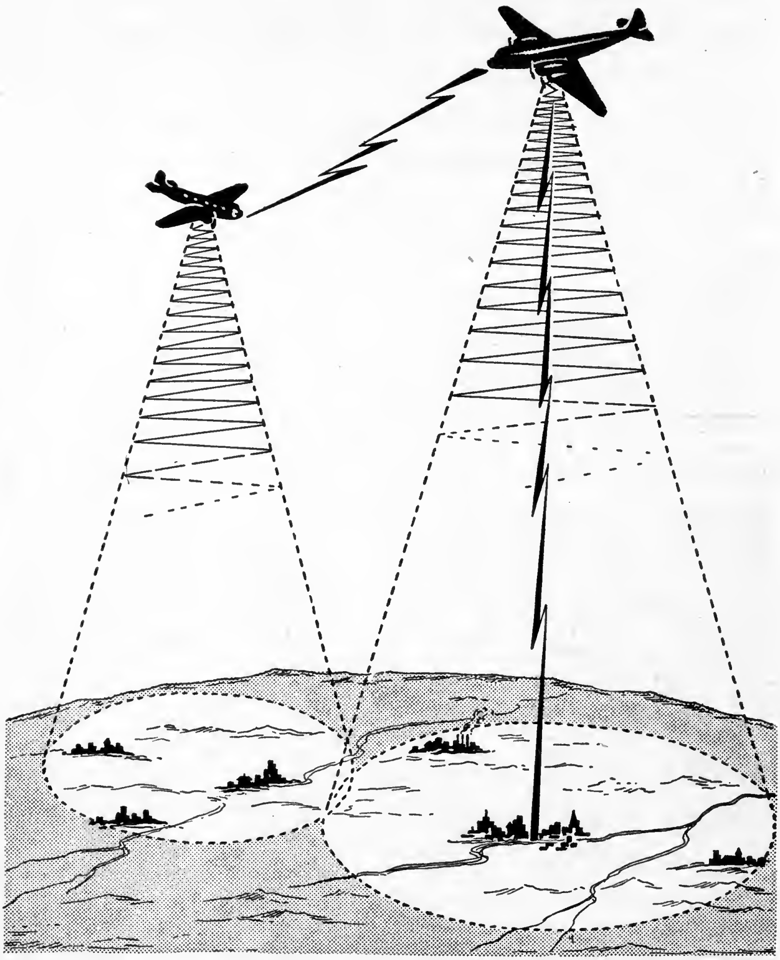
Courtesy of N.B.C.

N.B.C. MICRO-WAVE ANTENNA USED TO RELAY TENNIS MATCH TO MAIN TRANSMITTER IN EMPIRE STATE BUILDING, NEW YORK ment in case of a failure of a tube or other elements in the receivers or transmitter. In case of power line failure they can switch automatically to battery operation. In this way stations in remote places on mountain tops can operate unattended. In many locations, during the winter months it would be impossible to reach the stations. These stations are being installed at present and it will not be long before they can be utilized for national television network.

This is not the only method of establishing television networks. As we have mentioned a special coaxial cable can be used between cities. This system has some advantages, because interference from storms and man-made static would be eliminated. The American Telephone and Telegraph Company outlined a schedule some time ago for installing these lines between our large cities. These links will be between New York and Washington, New York and Boston, Washington and Charlotte, Chicago and Terre Haute and St. Louis, and Los Angeles and Phoenix. It is hoped that by 1950 this system will extend from coast to coast.

Colored television has been transmitted over one of these lines between New York and Washington. This was done in the spring of 1946 by the Columbia Broadcasting System to demonstrate network colored television. News events have been telecast simultaneously in New York and Washington by use of this cable.

Still another system is being developed by Westinghouse Electric Corporation. This system is called Stratovision and



STRATOVISION SYSTEM

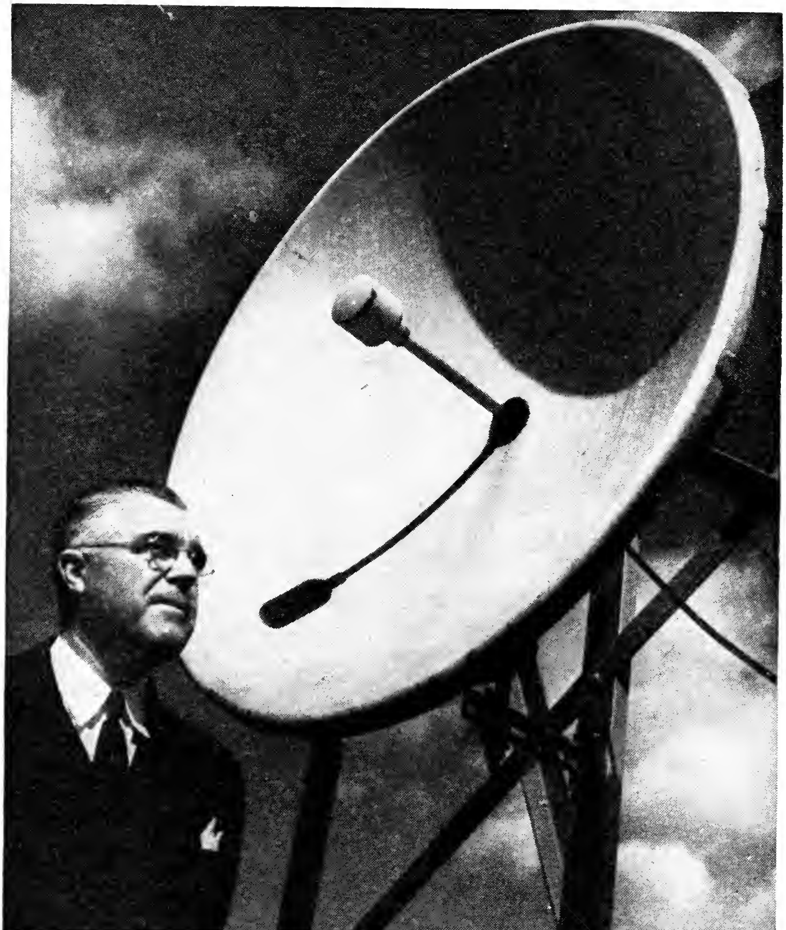
C.B.S., N.B.C., AND DUMONT, TRANSIENT TELEVISION PICTURES OVER COAXIAL CABLE BETWEEN NEW YORK AND WASHINGTON it utilizes planes flying at high altitudes to secure greater coverage. This system would serve a dual purpose—first, it would afford greater coverage by an individual transmitting station, and second, it would therefore require fewer stations to establish a network. Television transmitters would be installed in these planes and programs would be relayed to the planes by a small ground transmitter. While this system has not been experimented with sufficiently to estimate its full value it should be mentioned as it appears to have great merit.

In the stratovision system, the transmitting plane would fly in circles at approximately 30,000 feet or roughly six miles above the earth. The program would be transmitted to this plane by a small ground transmitter with a directional antenna system. The directional ground antenna would send the signal upwards towards the stratovision plane. A television receiver in the plane would pick up the program. This program would then be fed to the main television transmitter in the plane, and would be retransmitted back towards the earth to the various home receivers. Owing to the height of the plane the station could cover an area of 100,000 square miles in this manner.

If this were done by a plane flying above Pittsburgh, for example, six or eight other large cities could be covered simultaneously. This would include such large cities as Buffalo, Cleveland, Washington, Charleston and hundreds of smaller towns and villages.

Courtesy of R.C.A.

TYPICAL RELAY TOWN WITH HIGHLY DIRECTIVE RE-
CEIVING AND TRANSMITTING ANTENNAS



Courtesy of R.C.A.

HIGHLY DIRECTIVE RELAY ANTENNA USED FOR ULTRA HIGH FREQUENCY WORK

At the same time, the plane could relay programs to another high-flying plane. This second plane might be over New York City. It could pick up the program and retransmit it, thus covering such areas as lower New York State, Connecticut, Massachusetts, Rhode Island, etc. It is estimated that eight such stratovision planes could relay the program from coast to coast. It is believed that fourteen such planes could bring a television program to approximately 78 per cent of the country's population.

It is also possible with this system to transmit more than one program. A good-sized plane might house three or four television transmitters. The plane could carry a crew of three, and six television technicians. Four planes would be used for each transmitting point, two in the air and two on the ground. The second plane in the air would act as a stand-by in case of equipment or plane failure. The equipment in the ground planes would be serviced while the other planes were operating. When the operating planes came down for refueling and servicing the ground planes would replace them.

To take care of weather conditions the planes could shift their operating locations to other cities having better weather conditions. Each plane could shift approximately 200 miles and still cover the larger cities. Some locations in between the larger cities might be affected slightly.

The cost of a system like this is high in comparison with operating a ground station. However, the creators of this system point out that a single transmitter operating from a plane might eliminate six or eight large ground stations. The cost of six or eight large ground stations plus relay stations might be more than the cost of the stratovision system. This is the reason the Westinghouse Electric Corporation believes the system will be practical. The fact that more than one transmitter can be installed in a plane, making it possible to transmit two or three programs, also reduces the over-all cost.

Each time a program is picked up and retransmitted certain losses occur. Some static is picked up as the program is relayed from city to city. The equipment also may cause distortion, even if a program is only relayed two or three times, but these losses will not affect the program to any considerable extent. However, if it is relayed 10, 20, 30 or 40 times the distortion may be so great that the program is spoiled. Therefore large thickly populated areas might be covered with one, two or three relay stations, or with stratovision. The program might be transmitted in several directions from the main station, fanning out to cover a large area. If New York were the location of the main transmitting station the program might be relayed to Washington, D. C., Albany, New York, or Boston, Massachusetts. At the same time the program could be sent over coaxial lines to Chicago where another main station would transmit it and relay it to other localities around Chicago. The program could then be sent to the West Coast by coaxial and relayed to cities up and down the coast. In this way a program originating in New York could be sent to most of the thickly populated areas in the United States with the minimum amount of distortion.

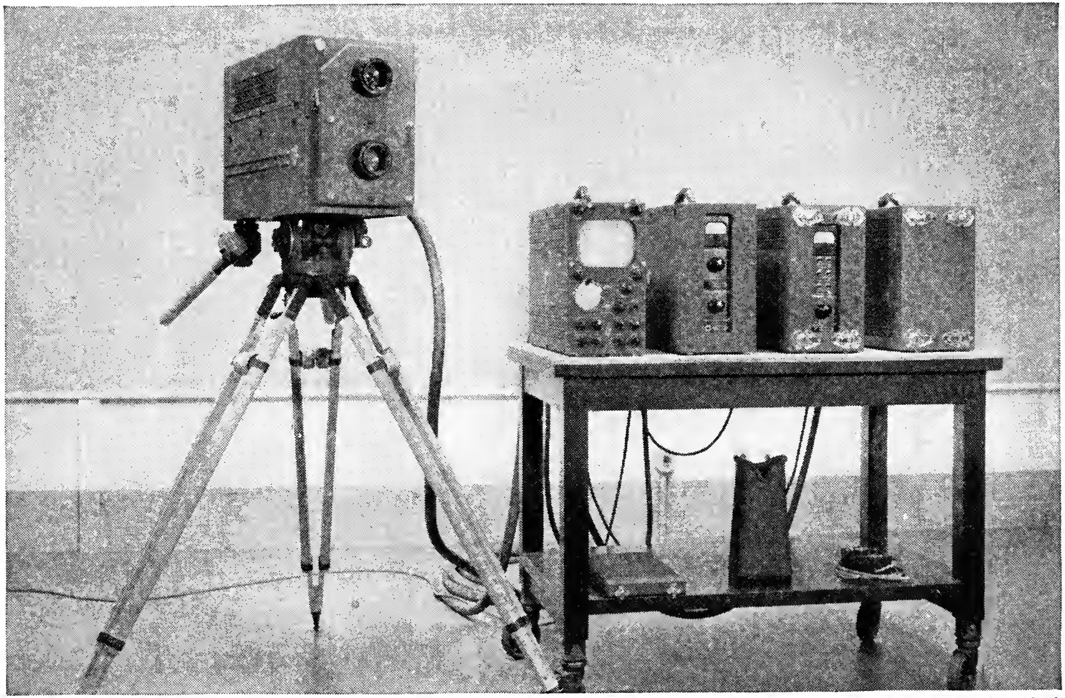
With network systems of this type, television stations could expect to receive fairly high revenue which would allow them to produce excellent programs.

Chapter Eleven

TELEVISION MOBILE EQUIPMENT

THAT television equipment should be as flexible as radio equipment was recognized early by the engineers. That is, they realized that in order to give the public good entertainment, it should be possible to pick up programs or events at almost any location. This meant the development of special portable equipment that could be set up at any location for news events, sports, and special features.

For this purpose light cameras were developed which are mounted on a tripod base. Each of these units is about the size of a suit case so it can be transported by car, railroad or plane. One control unit is used for each camera. If three cameras are necessary, three control units are used. Each control unit is coupled to a separate unit which sup-

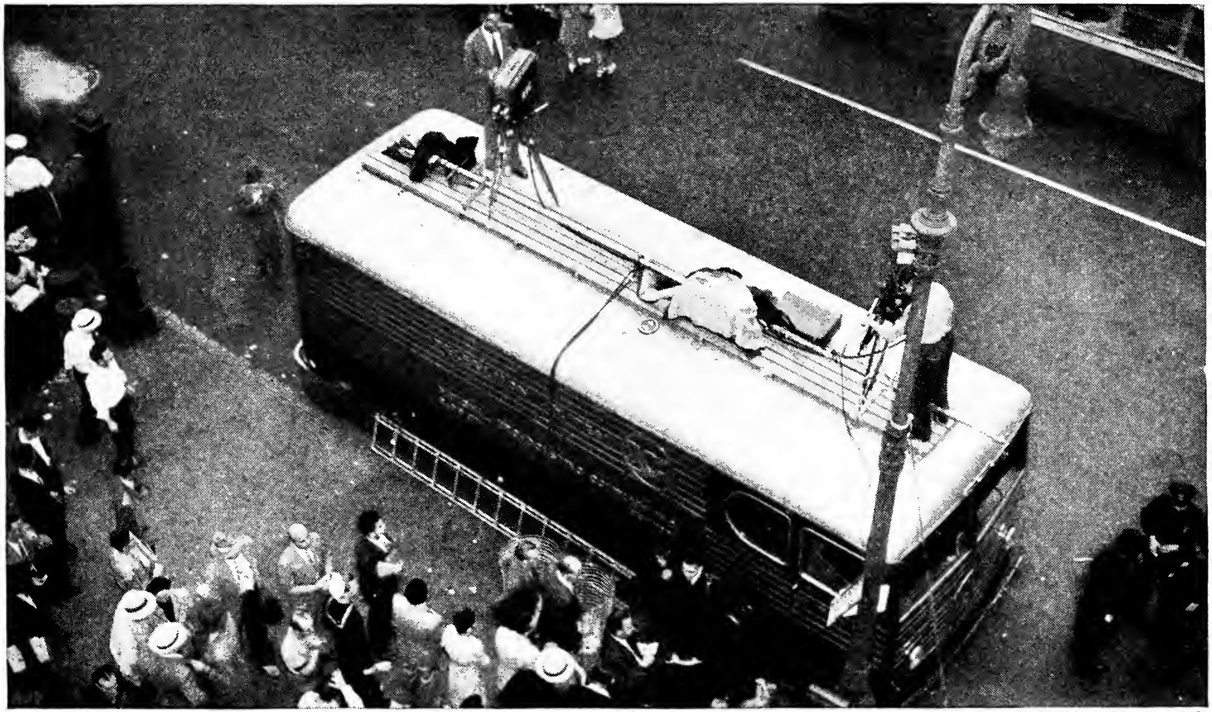


Courtesy of R.C.A.

CAMERA AND REMOTE PICKUP EQUIPMENT USED FOR TELECASTING SPORTS EVENTS plies power of proper voltages for the operation of the various tubes in the control unit. The camera control unit is equipped with a picture monitor tube and an oscilloscope tube. The oscilloscope tube is for checking the frequency of the scanning signal. Associated with the monitor tube in the camera control unit are controls for adjusting brightness, shading and synchronizing. The camera control units are also connected to a separate unit called a master control unit which can handle two or three cameras. It is equipped with two monitor picture tubes, and is used principally for camera switching. The operator can switch to any one of the three cameras and visually check the outgoing picture. The master control unit also has a separate power supply.

There are two additional units used with this equipment and they are called the shaping unit and the pulse unit. These units supply the signal necessary for picture scanning. If there is A.C. power available and coaxial telephone lines to the main transmitter, this is all the equipment necessary for a field television pickup, with the exception of sound pickup. For sound pickup standard portable broadcast equipment is used.

If there is no coaxial line between the pickup location and the main television transmitter then another unit is used. This unit consists of a small portable transmitter and antenna system. This is connected to the master control unit and it transmits the television program to the main television transmitter which retransmits it to your home.

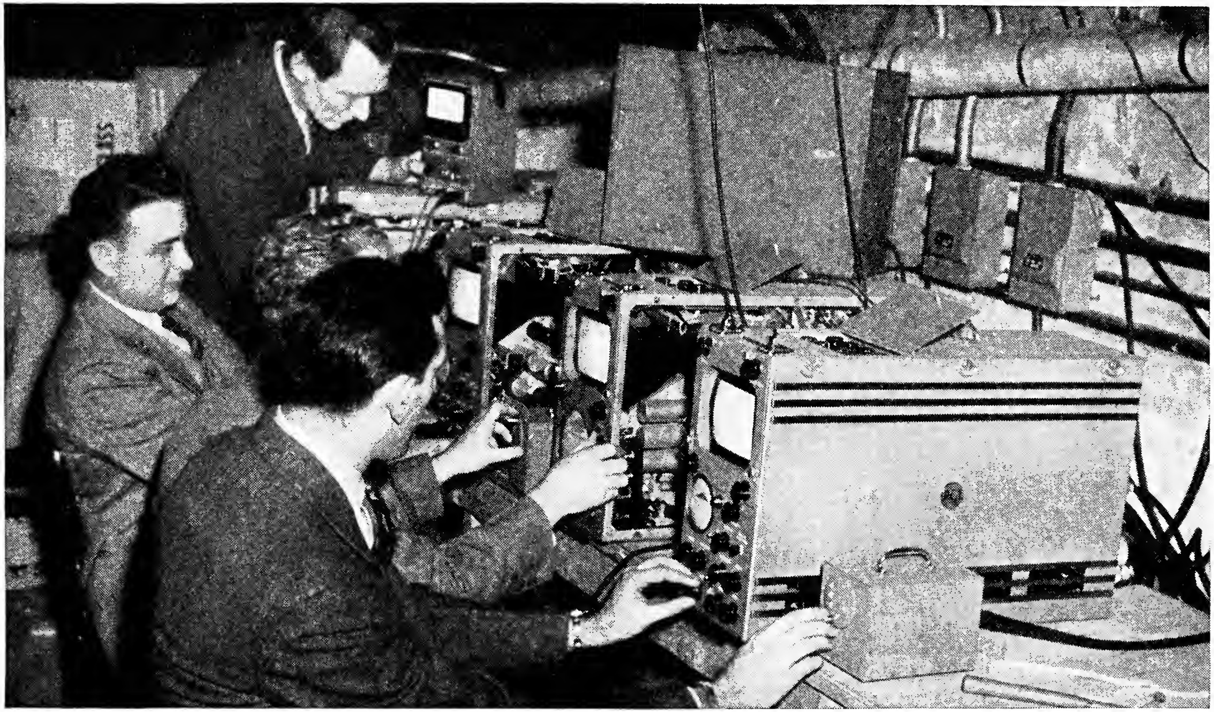


Courtesy of N.B.C.

N.B.C. MOBILE TRUCK FOR REMOTE PICKUPS

To use this type of equipment, power must be available at the pickup point. For more difficult pickup points, R.C.A. has developed mobile field equipment. This equipment is all carried in trucks. Two trucks are used. One truck houses the monitor equipment for both picture and sound. The other truck carries a 400-watt transmitting station and antenna system. The antenna folds flat against the roof of the truck and is raised when the mobile unit is set up for telecasting.

This first truck acts as the television control room. The cameras and microphones are connected to the truck by cables equipped with plugs. There is a platform on top of the control room truck so cameras can operate from this vantage point. Inside the truck there is portable television monitor camera equipment similar to the type just described. With this equipment most of the normal functions of a television studio control room can be carried out—camera switching, picture shading, adjusting the brightness and contrast can be accomplished. The sound monitoring equipment is also carried in this truck. Several microphones can be used and they are monitored by a loud-speaker inside the mobile control room. For picking up sound from the top of the truck, a microphone with a parabolic reflector is used. This is a dish-shaped reflector about three feet in diameter. The microphone is mounted facing this reflector so the sound waves first strike the curved surface of the reflector, which directs the sound waves toward the microphone. This unit can be used to pick up such sounds as a batter striking a



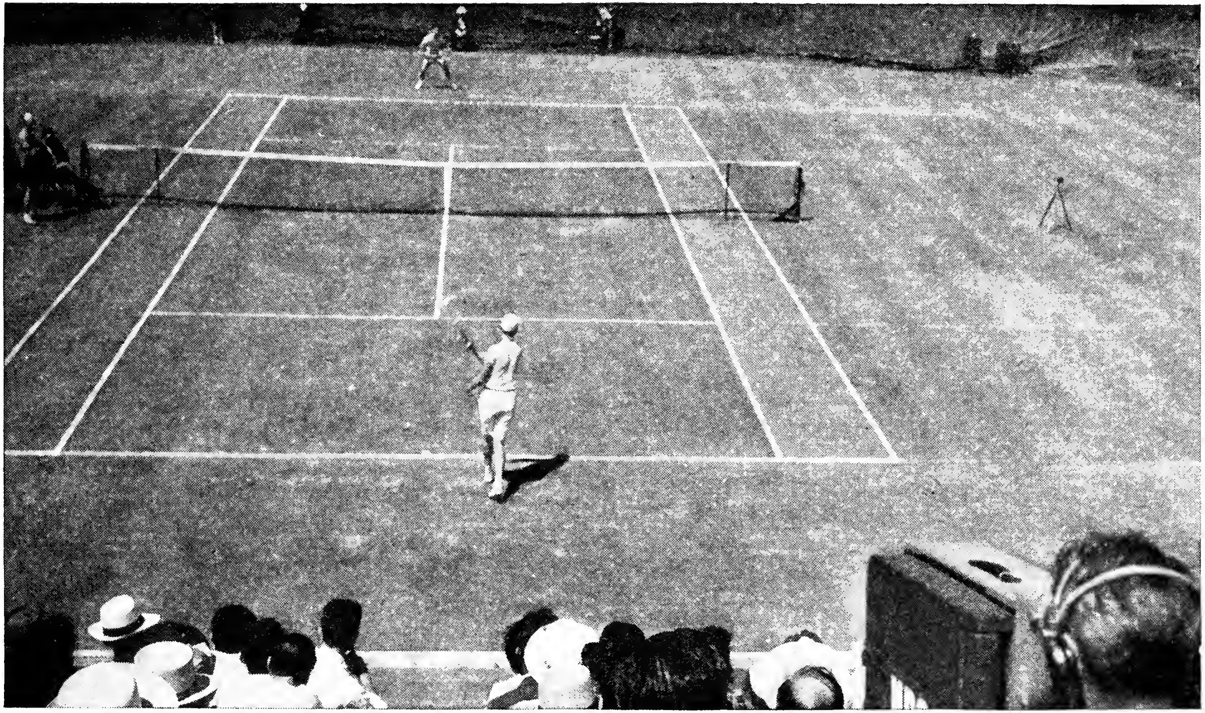
Courtesy of C.B.S.

TELEVISION REMOTE PICKUP PORTABLE MONITOR EQUIPMENT ball.

The cameras used with the mobile pickup equipment have several lenses of different focal length. Long focal length telescopic lenses are used for action which is a considerable distance from the truck.

This equipment gives the mobile unit great flexibility. It can be driven to a baseball field and set up to transmit an entire game. Usually for work of this type the trucks are placed along the base line. One camera with a telescopic lens is set up on top of the truck to photograph the action at the bases or in the outfield. Another camera with a shorter focal length lens is set up near home-plate where the action is closer to the camera. This camera can be used to photograph the pitcher and the batter. A setup of this type is handled in the following manner. The camera near home-plate photographs the pitcher winding up, then swings to photograph the batter. If the batter hits the ball, the sound can be picked up by the parabolic microphone. When this happens the cameraman follows the batter as he runs to first base. The cameraman on top of the mobile unit focuses his camera on the player who will try to make the catch. Just before the ball reaches the player, the video man in the control room below switches cameras so this action is telecast. The telescopic lens makes the picture look as if the camera were placed close by the action.

This action which has been transferred by the camera into an electrical signal passes through the control room of



Courtesy of N.B.C.

N.B.C. TELEVISION IMAGE ORTHICON CAMERA FOCUSED ON TENNIS MATCH the first truck. At this point the video engineers make adjustments in picture brightness and correct other defects in picture transmission. The picture impulses then go by cable to the second truck. Here the signal is amplified and combined with the carrier wave generated by the transmitter for broadcasting. This transmitter, however, does not send the program to your home. The antenna system on the roof of the truck is a directional antenna system and it is used to send the program to the main transmitting station. N.B.C. uses this system quite often to send television programs to their main station in the Empire State Building at 34th Street and 5th Avenue, New York City. Here the program is picked up by a receiving antenna, amplified and fed to the main transmitter located on the top floor of the building. In this way, the program is retransmitted to the people living in and around New York City.

In cases where there is no power available at the pickup point, a mobile generator is used. This unit is in the form of a trailer attached to the back of the transmitting truck. It is a gasoline engine generator with sufficient capacity to operate the transmitter and video equipment. This generator increases the operating scope of the mobile television unit. For instance, it can be driven to almost any part of New York City and action pictures can be sent to people with television receivers. Such a unit was driven to Times Square on V-J Day and the scene was transmitted to television sets in New York City. This equipment can be used to transmit almost any type of event from a horse race to a disaster.

Chapter Twelve

COLORED TELEVISION

COLORED television is only new to the extent that its development has reached a point where it is commercially sound. It has been in the development stage for 18 or 20 years and in the last 5 or 6 years it has progressed from a crude experiment to high quality colored pictures equal to, or better than 16 mm. colored movies. Even before the war high quality colored pictures were being transmitted and received experimentally. In fact, if the war had not interrupted television, colored receivers might have been on the market by 1943 or 1944. These receivers would have produced colored pictures providing greater clarity than the black and white pictures which were being televised at that time.

One of the drawbacks to early television was the size of the television screen. While methods were being developed to produce large screen television pictures by projection, there was a limiting factor to the size of the picture that could be produced with good results. This limiting factor is the number of picture elements which can be transmitted. As you enlarge a picture, these particles which make up the picture become evident. If a transmitted picture contains enough of these small elements it can be enlarged to quite an extent before it becomes too coarse to be considered of good quality. Pre-war 441 line television pictures, however, began to lose quality and definition as soon as they were enlarged to 18 x 24 inches. Of course, the answer to this problem is quite simple—produce a picture with more picture elements. While the answer is simple, the problem is quite complicated. In order to do this in television, the scanning must be changed, as each scanning line contains a certain number of picture elements. So to increase the elements it is necessary to increase the number of scanning lines. This can be done, but it also affects the transmission because it requires a broader frequency band. It was not practical with the frequency band allotted to pre-war television. It could be done, however, by going to a higher carrier wave frequency. Pre-war television was transmitting on carrier wave frequencies below 200 M.C. If this were raised to 400 M.C., pictures containing more lines, hence more detail, could be transmitted. This would improve black and white transmission as well as color. The drawbacks to this idea were that little was known about the engineering problems involved in transmitting television at these frequencies, and that even if it proved to be practical, all pre-war receivers would be obsolete.

During the war a great deal was learned through radar about transmission at super-high frequencies. Also new methods of transmission were developed which could affect television and radio transmission. This development was so rapid during the war, that what would have taken 10 to 20 years during normal times was accomplished.

The Federal Communications Commission, when it reallocated frequencies, assigned an experimental band of frequencies to television. This experimental band was between 480 and 920 megacycles. The Columbia Broadcasting System, which has been promoting and developing colored television since before the war, applied for a license to transmit at these new frequencies. This would allow them to transmit their colored system and produce pictures with even more clarity than they could obtain before the war. They could also transmit black and white pictures over the same system, and these pictures would be of a much higher quality than any produced prior to the war. Furthermore Columbia could utilize a new system of transmission developed during the war which required only a single transmitter and antenna for both sound and picture, whereas the pre-war system required two transmitters, one for picture and one for sound, and two antennas.

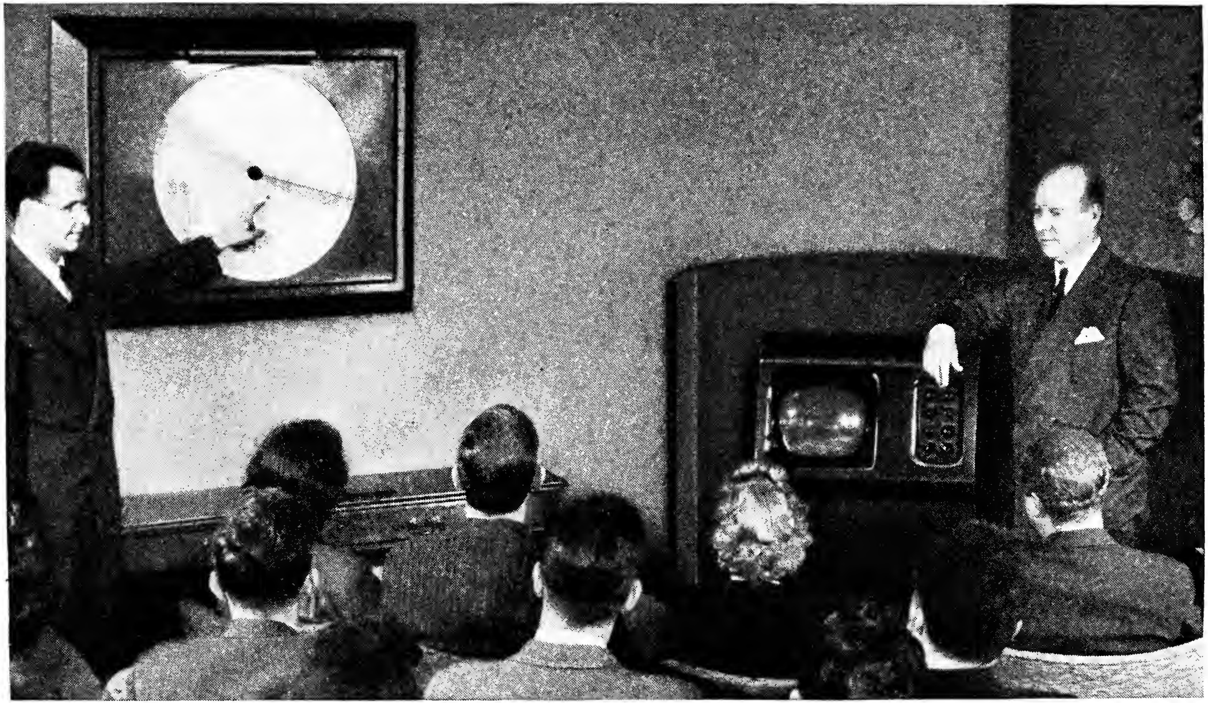
This new colored system was demonstrated within six months after V-J Day. Demonstrations were put on for the press and people in the broadcasting business. The demonstrations were highly successful and many viewers felt that the new system would make pre-war television standards obsolete.

To demonstrate this system special television equipment was developed by the Columbia Broadcasting System and the Federal Telephone and Radio Corporation.

F. T. Company (Federal Telephone and Radio Corporation) designed and built the television transmitter which is capable of transmitting the high frequencies necessary for televising high definition black and white and colored pictures.

The Columbia Broadcasting System designed and built the colored film scanner which transmits colored pictures from colored motion picture film. This machine breaks the picture down into three primary colors, each color being transmitted separately. The Columbia Broadcasting System also designed and built two different types of colored receivers—a direct-viewing and a projection type of receiver. These machines were developed for demonstration purposes. A special motor-driven receiver antenna was also designed. This was a directional type of receiving antenna which could be rotated by means of a motor.

The colored film scanner or the colored dissecting machine was located in the Columbia Broadcasting System offices at 485 Madison Avenue, New York City. The colored picture impulses developed by this machine were sent over coaxial lines to the 71st floor of the Chrysler Building, New York



Courtesy of C.B.S.

DEMONSTRATION OF COLORED TELEVISION ANTENNA INDICATOR UPPER LEFT HAND CORNER

City. The new C.B.S. transmitter was installed on this floor to televise colored pictures. The colored impulses coming from 485 Madison Avenue were used to feed this transmitter. The antenna system used in conjunction with this transmitter was mounted outside of the windows on the 71st floor; there two antennas were installed—one on the north side of the building and one on the south side.

The transmitter combines the colored picture and sound impulses coming from the colored film scanner with the carrier wave developed by the transmitter. As with a black and white television transmitter, this carrier wave is used to carry this impulse via the air to the receiver. The carrier wave is radiated by the antenna system as heat is by an ordinary radiator.

One of the fears about transmitting these very high frequencies was the danger of reflected waves. Because these waves function much the way light does, they are reflected by hard surfaces. The waves bounce off all the various buildings with which they come in contact. This condition also exists with the lower frequencies (below 200 M.C.) used for television. It was felt that these new higher frequencies would produce even more reflected waves, causing ghost images, than the lower frequencies. Because of this, a special directional receiving antenna was developed by the Columbia Broadcasting System for colored television. This antenna system produced some astonishing results.

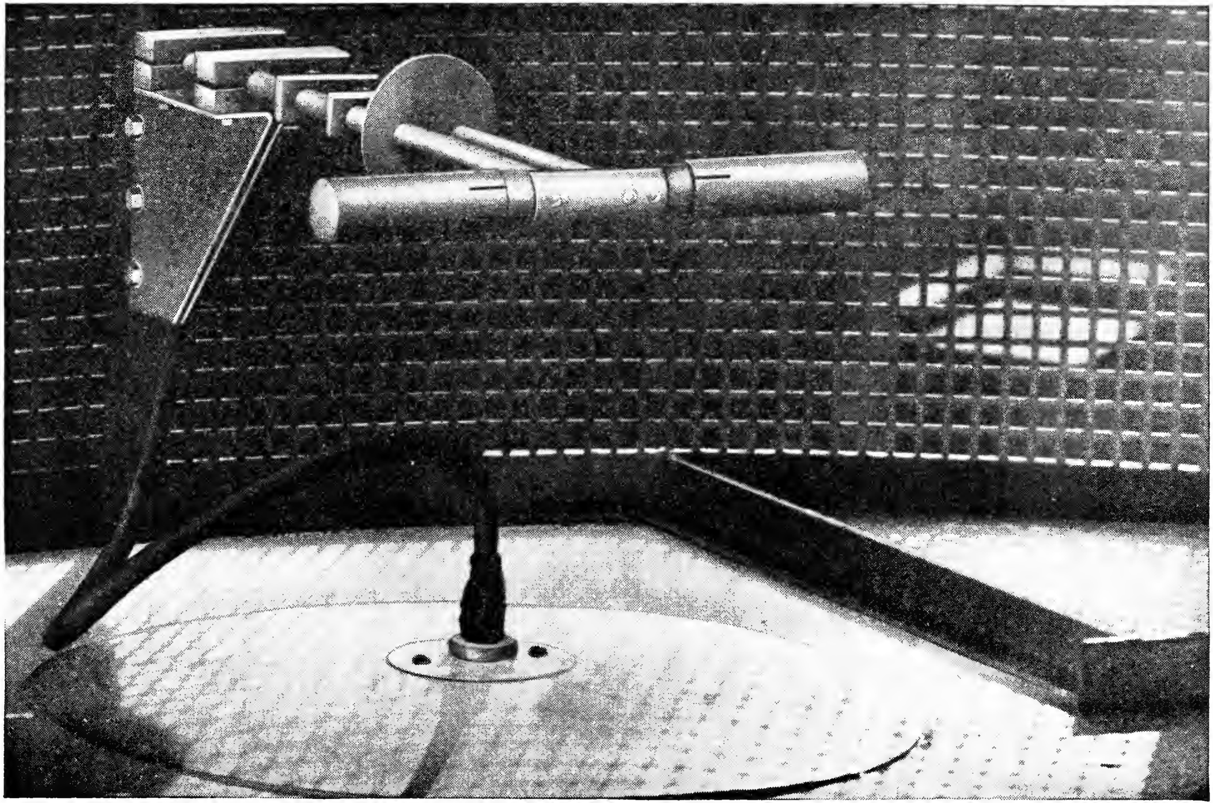
These antennas work in exact reverse to a directional transmitting antenna. A reflector is used behind the antenna system to reflect all the energy coming from a certain direction back onto the antenna, thus functioning the way a link receiving antenna does. The drawback to this antenna system is that it is directional and will only receive radio energy coming from a certain direction. So the antenna must be aimed at the transmitting station. If you want to switch from one station to another and they are located in opposite directions, the antenna system has to be turned around until it faces the other station. Because of this the receiving antenna was designed to rotate. It is rotated by means of an electrical motor which is controlled by a push button near the receiver. Recently new antennas have been designed which automatically focus on the transmitting station or the strongest reflected wave.

For experimental and demonstration purposes it was also desirable to be able to know the direction the receiving antenna was facing. The direction was indicated by a dial near the receiver. This was accomplished by Selsyn motors. These motors are used for many purposes, such as gun fire control. They are not generally used to operate equipment, but they are used as indicators or controls. They consist of two motors which are electrically interlocked, so that when one motor is turned 1/4, 1/2 or 7/8ths of a revolution the other motor will turn 1/4, 1/2 or 7/8ths of a revolution. The motors may be located a considerable distance apart and connected by means of wires.

One motor was connected to the rotating antenna by a series of gears so the motor would be rotated as the antenna was turned. The other motor was located near the colored television receiver, and attached to this motor shaft was an indicator which would rotate as the antenna did. The indicator was mounted on a map of New York City and it showed what section of the city the antenna was facing. These two motors were locked together electrically just as if their motor shafts were tied together, even though they were located some distance apart. Thus the receiving antenna was equipped with two motors, geared to the antenna system. One motor was used to rotate the antenna and the other for indicating its direction. The antenna was a dipole type with a curved reflector behind it.

This system enabled the engineers to watch the colored television screen on the receiver while they rotated the antenna. The experiment proved that a receiver equipped with a directional receiving antenna of the type just described is practically void of ghost images. The antenna could be rotated while receiving a program and it was very difficult to produce ghost images.

This antenna proved another point which had been troubling the engineers. It had always been thought that it would be difficult to receive a program if any obstacle was between the receiving antenna and the transmitting point, the reason being that waves of this frequency travel in a straight line. A demonstration with this receiving antenna proved that this



Courtesy of C.B.S.

COLORED TELEVISION ROTATING RECEIVING ANTENNA also was not true.

During the demonstration of colored television the antenna was rotated so that the viewers could see the results. The map and antenna indicator were mounted on a wall beside the colored receiver so the viewers could watch the picture and see the position of the receiving antenna at the same time. As the antenna was rotated the picture would fade out completely when it was in certain positions, but often it passed this point and the picture would come back to its original brightness. It showed that the antenna would receive a signal of suitable strength when it was in any one of six or more positions. This meant that the antenna system was picking up signals which were reflected from various buildings. In fact, by watching the indicator, which showed the direction the antenna was facing, it was possible to tell what buildings were reflecting the signal.

To demonstrate this, the antenna was pointed toward the Empire State Building which is south of the Chrysler Building where the transmitter is located. In order to receive this signal, the wave has to travel away from the transmitting point toward the south and be reflected by the Empire State Building back north towards the receiving antenna. A signal of sufficient strength to produce good reception was received by this means. When the antenna was facing a point midway between these two buildings the picture faded out completely. The reason for this was that there were no tall buildings between these two points to reflect the wave. The same results were obtained by picking up waves reflected from other buildings near the receiving antenna.

This type of receiving antenna proved that good reception of colored or high quality black and white pictures could be obtained at these new high frequencies. It proved that even though the receiver might be located between tall buildings, good reception could be achieved.

The change-over to this new system may be slow because manufacturers have a considerable investment in the old system. However, demonstrations have proved the new system to be sound. The cost of these new receivers will probably not be any higher than that of the first black and white receivers. As more manufacturers produce them the price will drop so that the difference in cost between the old and new type receivers will be small.

The new color receivers can be designed to receive pictures in black and white or in color. That is, they can receive both providing the receiver operates at the new super-high frequencies. This could also be done at the lower frequencies, around 200 M.C., but fewer lines could be used, hence there would be less detail.

In short, regardless of where your color receiver may be located geographically, you can expect to receive good color reception. With a new receiver you can see baseball, football or your favorite program in full color within a short time.

Chapter Thirteen

THE COLORED TELEVISION CAMERA

WHEN you first think of color being transmitted electrically, it seems like an impossibility. Most people also felt that way about black and white television before they learned how it functioned. However, colored picture transmission seems even more fantastic than black and white. But once you understand how black and white television is accomplished, learning the fundamentals of color transmission is quite simple. As a matter of fact, adding color to television required much less engineering work than was necessary to produce the first commercial black and white television pictures.

Most people are aware that three primary colors can be blended together to produce any desired color. Blue and yellow mixed together produce green, red and blue, purple, and so forth. This is true of paint, and it is also true of colored light. With paints, red, yellow and blue are the primary colors. With light, any three colors can be selected as primary colors, provided they contain the colors necessary to produce the basic colors of the spectrum—red, blue and yellow. The colored television system uses red, blue and green as its primary colors.

The fundamentals of three-color television transmission are the same for picking up a live scene as for transmitting a picture from colored film. The major difference is the need, in transmitting from film, to synchronize the scanning with film motion, whereas in live talent pickup this is not necessary.

To transmit color, the scene is broken down into the three primary colors—red, green and blue. This is done by the use of color filters. The filter consists of colored glass or gelatin. If a scene is projected through a color filter by means of a lens system this filter will remove all colors except the color contained in the filter. As an example, if a blue filter were placed between the lens system and the photosensitive material of the camera pickup tube, only the blue parts of the picture, such as the sky, would appear on the photosensitive material. When this image, containing the various parts of the picture which are blue, appears on the photosensitive plate of the camera tube then the blue parts of the picture can be scanned and transmitted. If this image were received and reproduced on a receiving tube, you would

Courtesy of C.B.S.

NEW C.B.S. PICKUP COLOR TELEVISION CAMERA FOR USE IN THE ULTRA-HIGH FREQUENCIES see only the parts of the picture which contain blue. You would see these parts as various shades of gray, for no color is actually transmitted—just impulses which represent the parts of the picture containing blue. But if you placed another blue filter in front of this receiving tube you would then see the blues contained in the original picture, even the blue in the green and purple parts of the picture. They would appear as various shades of blue. This same process can be done with a green filter. In this case, all the greens would be transmitted. If a red filter were used, all the reds would be reproduced on the receiver.

This is exactly what the color camera and receiver do—they transmit and receive each color separately. They are transmitted in this order: all the reds first, the blues second and the greens third. If this transmission is rapid enough, the colors blend together and the eye cannot detect the fact that each color is transmitted separately.

The trick to this system is to be able to filter each picture rapidly and to synchronize the impulses at the receiver. As each picture is scanned, the proper-colored filter has to be placed between the lens system and the camera pickup tube. This also applies to the receiving tube as each picture is traced out. The proper filter must be placed in front of it.

This is done within the camera in either of two ways. In the direct pickup camera, a rotating drum containing the filter is used. For film scanning, a rotating flat disc is used which acts as a filter selector. This process will be described separately.

This drum is rotated by means of a motor so that each filter passes in front of the camera pickup tube while a single scanning operation is being completed. Twenty complete pictures per second are transmitted—each picture being filtered three times. This works out so that a 1,440 revolution per minute motor driving a filter disc containing six filters synchronizes perfectly with the scanning operations. The disc contains two red, two green and two blue filters. They are arranged in this order—red, blue, green, red, blue, green. This means that 8,640 color images are transmitted per minute and this is so rapid that the eye cannot detect the individual colors. When received, these colors appear to be mixed so that all the various colors in the picture appear as normal greens, browns, violet, etc.

Six scanning operations are used to produce each color picture transmitted. A single scanning operation for one color takes $1/144$th of a second. This is known as a color field. The first time a color is scanned, only the odd lines (1, 3, 5, etc.) are scanned. So the first three operations consist of scanning alternate lines for all three colors. Then alternate lines which were not scanned are scanned for all three colors, six operations in all. When one color has been scanned twice, both odd and even lines, it is called a color frame. Because the interlaced scanning of any one color is not done in succession, it takes $1/24$th of a second to produce a color frame. The entire operation to produce one full colored picture takes $\frac{1}{48}$th of a second.

The receiving set also has a color filter. In the case of a direct-viewing receiver, a large disc is used. This disc is mounted inside the receiver cabinet and rotates so the filters pass in front of the television receiving screen. This disc rotates at the same speed as the camera filter, 1,440 R.P.M., and it also contains six filters—two reds, two blues and two greens, arranged in the same order as the camera filter.

The camera motor and the receiver filter motor must be synchronized with the scanning operation. If the motor rotates a little too fast or slow, the scanning and filtering would be out of step, causing the picture to be distorted. Keeping the scanning and the filtering in step is one of the secrets of the success of this system.

On the motor shaft that drives the filter, a special electronic brake is used. This brake controls the speed of the motor, so that it cannot rotate too fast or too slow. This brake is controlled by the scanning impulses so it keeps the motor in step with the scanning operation. In the receiver, the same impulses which are received to produce the scanning operations are also used to put the filter wheel in step with pictures produced on the receiver screen.

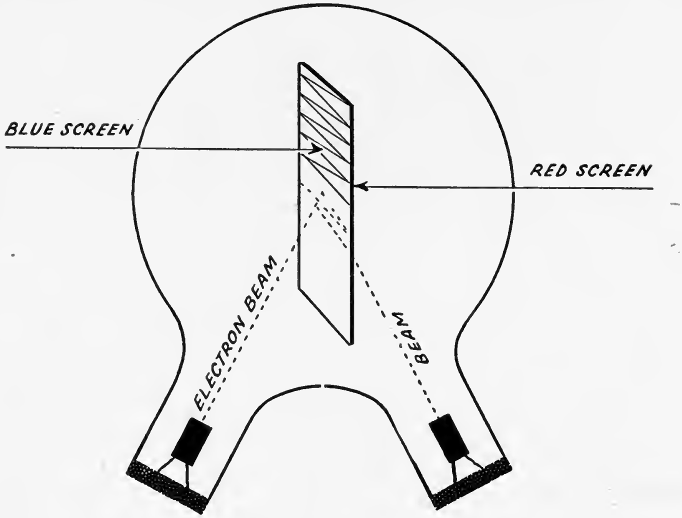
The color of the light falling on objects to be transmitted can cause a colored television picture to be out of color balance. If the light used to illuminate a screen contains a great deal of yellow, then the blues in the picture will appear green. Red or violet light also causes color distortion. This is the reason you often mistake blue for green under artificial light. The color system just described can be adjusted to compensate for unbalanced color conditions in live pickups. It can also compensate for unbalanced conditions which may exist on color film when the program is being transmitted from film. When colored motion pictures are photographed, if the exposure is not correct, unbalanced conditions may exist in the processed film. The blues or reds may be more intense than the other colors, for instance. These corrections are made by a special device called a color mixer. It consists of a control panel containing three knobs which control the three primary colors. By adjusting these three controls the proper color balance can be obtained.

Electrically, the adjustment is accomplished by three amplifiers equipped with a special electronic circuit, and three intensity controls. The amplifiers increase the signal, the electronic circuit selects one of the three color impulses. The amplifiers are arranged so that each one selects a different color impulse. In other words, only one color impulse is allowed to pass through. The other two are canceled. This means that there is a red, a green and a blue amplifier and a control which operates as a volume control for the intensity of the various primary colors. As there are three color impulses being transmitted, the circuit in the amplifier is designed to select every third impulse. The impulse which is allowed to pass has an intensity control. As each amplifier selects a different primary color impulse and the intensity can be controlled, the color system can be balanced.

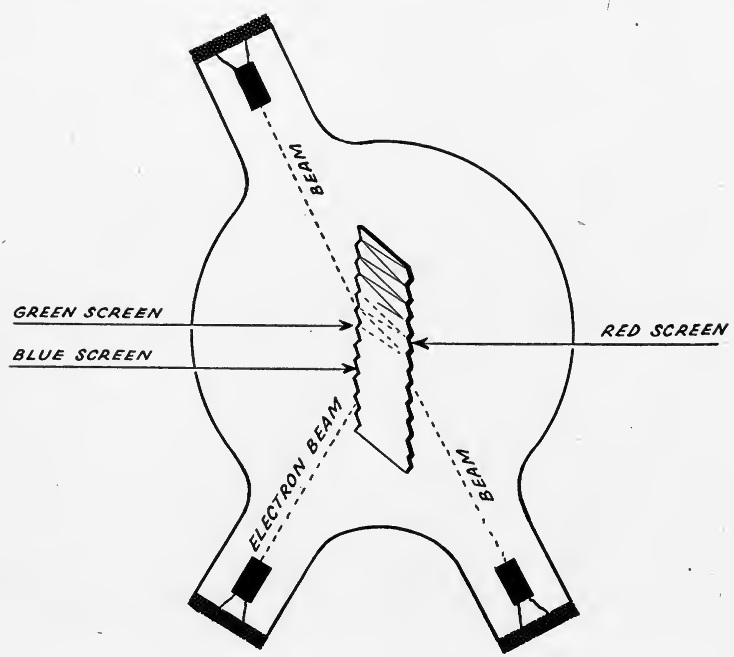
When all three colors are mixed together with the proper intensity the white portions of the picture are clear in tone. The technician who operates the color mixer watches any white portion of a picture, such as a man's white shirt, and adjusts the three colors until the shirt looks a clear white. If it does not look white he knows his colors are not properly balanced. If the shirt appears pink then the reds in the picture are too intense, so the technician reduces the red by making an adjustment with the red control knob. In other words, the white areas of the picture are a color check for the technician who views a color monitor screen. The picture is produced on the monitor screen in the same way as it is on a home receiver. The impulses are taken from one of the outgoing lines which feed the transmitting station.

As it is sometimes difficult to tell true white, the technician has a sample of true white alongside the screen. This sample is illuminated by a light which is as near true white as can be obtained. By matching this white with the white portions of the picture he can obtain true color balance.

This color mixer can also be used to obtain trick effects. If a scene is supposed to be outdoors, in the early evening, the technician can make the blue more intense, thereby giving the illusion of early evening. If the time is just before sunset he can add more red, giving a pinkish hue to the entire picture. A scene at a fire can be made more realistic by increasing the red portions of the picture. Increasing the greens



COLOR CAMERA TUBE FOR TWO-COLOR BAIRD SYSTEM



COLOR CAMERA TUBE FOR THREE-COLOR BAIRD SYSTEM can be used to produce an eerie effect.

This system of producing colored television is not the only known method. Other methods have been developed, but it is felt that the one described in this chapter has produced the best results. John L. Baird has developed in England a color system which requires no moving parts. He has experimented with several different systems, but they have not reached a point where they can be used commercially. However, in years to come, one of these systems may be adopted by the English as the basis of their colored television system.

The Baird system works on the principle of using two, or three, electron beams to produce the color picture. His two-color system uses blue-green and orange-red as the primary colors, and it is somewhat limited in producing true color balance. However, it does not require any mechanical device to produce the picture, as the colors are attained by electronic scanning. The colors are actually produced by a colored fluorescent material. The fluorescent material glows or transmits light of various colors, depending upon the materials used. In the two-color system the receiving tube uses a blue-green and an orange-red fluorescent material on the scanning surface. The screen is located inside a vacuum tube. The front of the screen is covered with blue-green fluorescent material and the back with an orange-red material. One electronic beam scans the front surface to produce the blue-green colors in the picture. The other beam is fired from the rear of the tube and covers the orange-red fluorescent screen. A transparent material is used between the two screens so the viewer sees the colors in both screens. Thus one electronic beam, operating in the same fashion as in a standard black and white television tube, produces all the blue-green colors in the picture. The other electronic scanning beam operating on the back screen produces all the necessary orange-red colors. The combination of the two screens produces most of the variations of color necessary to produce colored television pictures. Because this is a two primary color system it does not produce the color variations the three primary mechanical system does.

The three-color Baird system uses a corrugated surface on the front viewing screen. All the surfaces in one plane are covered with a green fluorescent material and in the other with a blue fluorescent material. The back surface is covered with a red phosphorous material, transparent material being used between the two screens. Three electronic beams are used for scanning. One electronic beam scans the green surfaces of the corrugated screen, while the other beam scans the blue surfaces. A third beam scans the back of the screen, supplying the reds necessary to produce the three primary colored pictures.

This system, while it produces most of the colors necessary for good color reproduction, has one major drawback. The colors are not produced on the same scanning lines. This leads to color distortion, so that certain colors in the picture are edged with the wrong color. The system has not as yet produced as good technical results as that developed by the Columbia Broadcasting System.

Mr. Baird at the time of his death was working on a newer system where successive color line scanning is used. This is also a purely electronic system. Alternate lines are used for the blue, green and red. To date it has not been developed sufficiently to make a fair comparison with the American mechanical system. Baird also worked on mechanical colored scanning systems and was one of the foremost inventors of colored television systems in Europe.

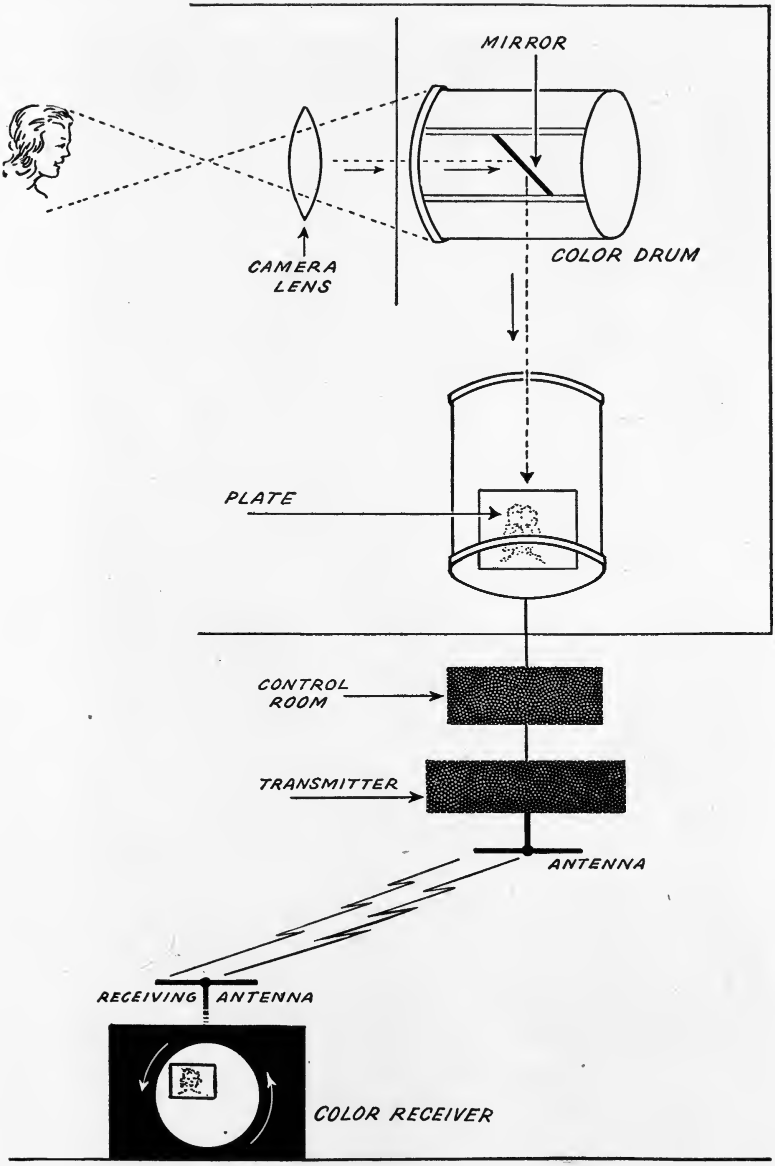
The United States will probably be the first to use colored television commercially. They have developed their system to a much higher degree than any European country. The quality is better than any other well-known system, though other systems undoubtedly will improve as time goes on. It will probably be only a short time before you will be able to purchase one of the new color receivers.

Chapter Fourteen

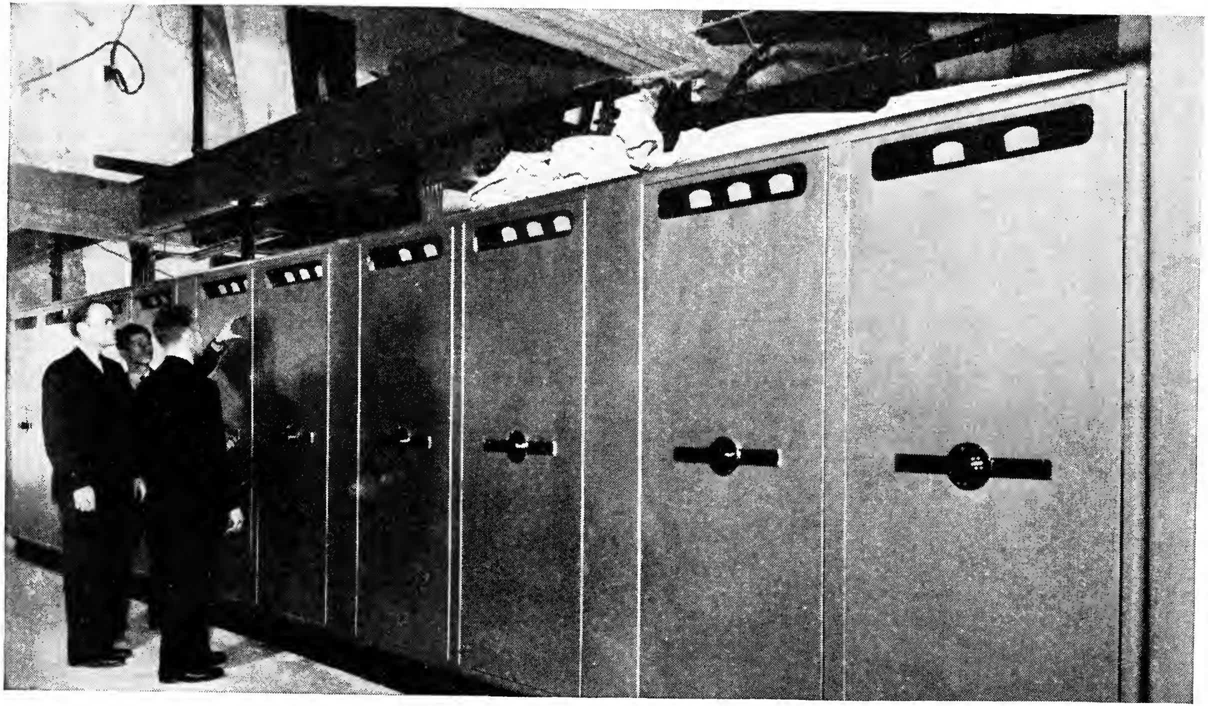
COLOR TRANSMISSION

COLORED television has been developed to a much higher degree than most people are aware. While the color system was being developed, Dr. Peter Goldmark of the Columbia Broadcasting System realized that it would have to be as flexible as black and white television. That is, besides being able to pick up scenes directly with a live pickup color camera, the system should be designed so that programs could be transmitted from colored motion picture film. Therefore he developed a system for transmitting pictures from colored motion picture film while he was designing the camera and receiver equipment.

This gives colored television great flexibility in program material. Travelogues, news events, educational pictures, animated cartoons and many other types of entertainment can be supplied by the use of 16 mm. colored motion picture



TELEVISION COLOR TRANSMISSION FROM CAMERA TO RECEIVER



Courtesy of C.B.S.

COLORED TELEVISION SOUND ON PICTURE TRANSMITTER film. Fashion shows and advertisements can also be transmitted in this manner. These pictures can be shipped from city to city, thereby eliminating the necessity of network television for all programs. This also allows the smaller television stations, which cannot afford elaborate television shows, to produce excellent program material.

This system also affords the producer of television shows more flexibility. Outdoor scenes can be taken on 16 mm. film and used in conjunction with a stage program. In the case of a small studio, stage scenery can be changed while program material is being produced from colored film.

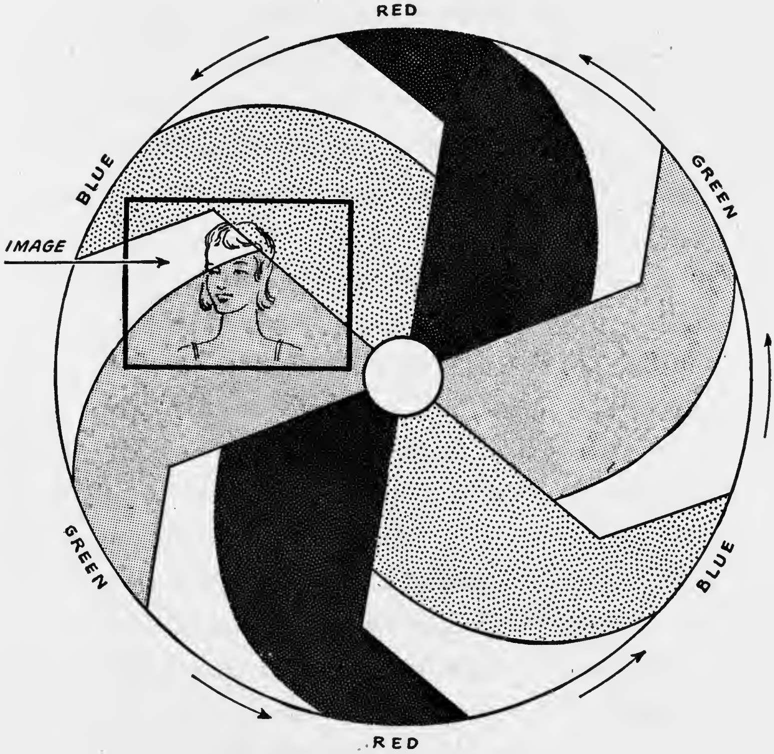
C.B.S. recently developed a new type color film dissecting machine. This film scanner is quite different in some respects from the early machines developed before the war. The prewar machine used a revolving color filter to break the picture down into the primary colors. In new machines, the color filters remain stationary but a special revolving disc selects the proper color filter. The machine is quite similar to a standard theater motion picture projector. It uses the same kind of arc lamp and film mechanism as the theater projectors, but differs from the theater projectors by its use of the color scanner and other equipment. It is designed to operate on 16 mm. film instead of 35 mm., normally used in theaters, because in 16 mm. color film more light can be concentrated on a smaller area. The arc lamp supplies sufficient light for 35 mm. film in normal motion picture work. When this light is concentrated on 16 mm. film a more brilliant picture can be projected on the television pickup tube.

The system uses the same number of color frames and fields as the direct pickup system. The dissecting process produces 48 color images and 144 color fields per second. It also operates on 525 scanning lines for each color field.

The sound is taken off the film in the same way as it is done in a standard motion picture machine. That is, the sound track runs down the side of the film and a separate optical system projects an image of the sound track onto a photoelectric cell. This cell changes the sound image back into an electrical signal. This electrical signal (audio) is the same type of signal as produced by a microphone.

The heart of the entire color film system is the selector disc, the selector lenses and the color filters. The selector disc consists of a round flat metal disc with six slots. The slots are curved, each one slightly closer to the center of the disc. Mounted in front of this disc are six co-planar lens segments. These lenses direct the light at the pickup tube. Each one of these lenses appears in front of the six slots in the rotating disc. Each lens is equipped with a color filter. This allows one color filter and one lens for each scanning operation, as six scanning operations are used for each complete picture.

The basic principle of the color film scanner is the same as the color pickup camera. It breaks the picture down into three primary colors: red, blue and green. Since two scanning operations are used for each color, there are six color filters and lenses. This is also the reason for six slots in the



COLOR FILTER DISC USED IN DIRECT-VIEWING COLOR RECEIVER

selector disc. The major difference between this and the color camera is that the filters are stationary, and the selector disc, which rotates, selects the proper filter.

As the selector rotates it allows the image from the film to first pass through the red filter and lens. Then the next slot in the selector disc allows the image to pass through the blue filter and lens. The third slot in the disc allows the picture to pass through the green filter and lens. The process is then repeated with the next three slots, filters and lenses. So one complete revolution of the disc provides six filtering operations. Because of interlaced scanning each color is scanned twice.

The image, after it has passed through the selector disc and the filters, is projected on the image plate of the electronic pickup tube by the co-planar lens.

So the film scanner first selects all the red parts of the picture and projects them onto the pickup tube. The pickup tube changes all these red parts into electrical impulses. Then the scanner selects all the blue parts of the picture and these are changed into electrical impulses. Then all the green parts are scanned and changed into electrical impulses by the pickup tube. Thus the film scanner transmits the picture in the same manner as the color camera, first transmitting all the reds, then the blues and finally the greens.

As interlaced scanning is used this is done twice for each complete color picture, known as a color frame.

The selector disc is driven at 1,440 revolutions per minute. As there are six filtering operations with each revolution this produces 8,640 color fields per minute. This is so fast that the eye cannot detect the filtering operations when the color receiver transfers the impulses back at the same speed. The human eye blends these primary colors together, so all the colors in the picture appear natural.

The color home receiver functions in the same way whether the picture is transmitted from film or from a direct pickup camera. There are two types of color receivers. One provides direct viewing and the other projects the picture on a screen. Basically these receivers are the same as black and white direct-viewing and projection receivers, the difference being that a color filter wheel has been added. Also there are additional electronic circuits to control the brake which keeps the color wheel synchronized with the picture scanning.

The major difference between the direct-viewing color receiver and the projection color receiver is in the color wheel. The direct-viewing receiver uses a flat disc whereas the projection type uses a cup-shaped color wheel. The projection color receiver is similar to a projection-type black and white receiver, in that a high intensity receiving tube is used. The tube is placed so it faces a disc-shaped reflector in the bottom of the cabinet. The reflector projects the image through a lens onto a mirror. The mirror projects the image onto a screen in front of the cabinet. The color wheel is mounted between the picture-receiving tube and the disc-shaped reflector.

This wheel is an odd shape so it does not get in the way of the projected image. It is shaped somewhat like a cup. Twelve filters are used and they are placed around the side of the cup-shaped wheel. The wheel only revolves at ½ the speed of the color filter drum used in the pickup camera. It also turns at ½ the speed of the selector disc used in film scanning. The reason for this is that twelve filters are used instead of six, so it only has to rotate at 720 R.P.M. instead of at 1,440 R.P.M. as in the pickup systems. In one revolution twelve filters pass the picture screen, whereas the camera, having only six filters, would have to make two revolutions to complete twelve filtering operations. There are four red filters, four blue filters and four green filters in this projection receiver wheel.

Twelve openings are cut in the side of this cup-shaped wheel. Each filter is mounted in a frame and covers one of these openings. As six filtering operations make one complete color picture, this wheel filters two complete pictures with each revolution.

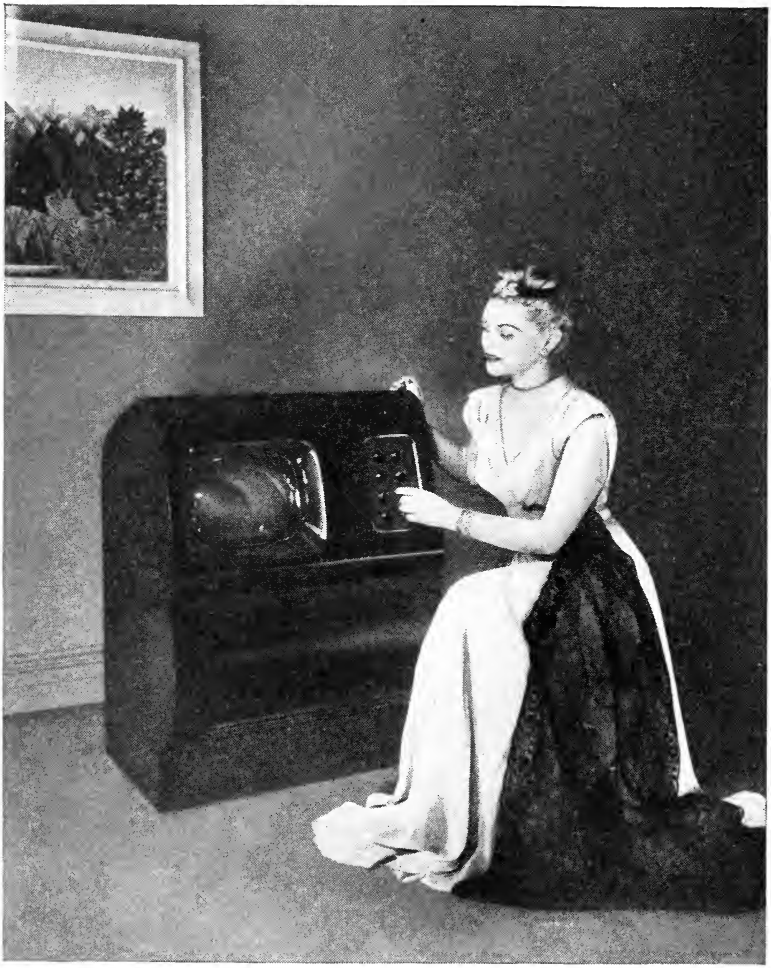
The wheel fits around the end of the picture tube. One end of the cup-shaped wheel is open, and it is placed so that one side of the cupped surface is in front of the tube. The inside of this wheel is concave. It is set at an angle so only part of the wheel is in front of the tube. In this way the rotating filter passes in front of the screen, then around the side of the tube. It fits close enough to the tube so little interference is caused by the picture being projected around the tube.

The viewer is not conscious of this filter as it is hidden with the projection tube in the bottom of the receiver cabinet. The cabinet is sound-proofed so as to eliminate the possibility of the motor and the wheel being heard by the viewer.

To review: Each filtering operation in the camera is duplicated by the receiver. A picture is filtered by a red filter in

Courtesy of C.B.S.

PROJECTION COLORED TELEVISION RECEIVER



Courtesy of C.B.S.

FULL COLOR DIRECT VIEWING RECEIVER

the camera so all the red parts are transmitted to the receiver. The receiver, by the use of another red filter, adds red to all the parts of the received picture where red is required. This process is then repeated by the blue and green filters in the camera and receiver. In this way the receiver reassembles the picture in full color.

The main object of this color projection system is to produce color pictures on a screen larger than the screens used in the direct-viewing receiver. This is one of the latest machines designed to receive colored television. It produces a picture approximately 18 x 24 inches. As more brilliant receiving tubes are developed, even larger pictures will be possible.

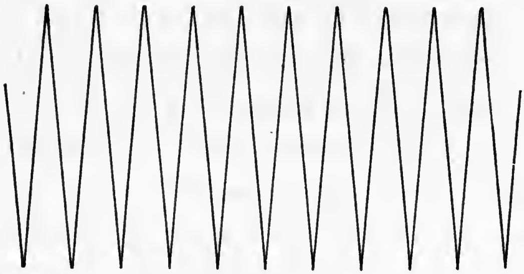
Chapter Fifteen

SOUND ON PICTURE TRANSMISSION

ALONG with colored television, new methods of sound transmission have been developed. Most people are familiar with Frequency Modulation even though they may not know how it functions. Multiplex, another method of sound transmission, was developed during the war and is now being used in conjunction with colored television. It is used to transmit sound—voice or music—combined with the picture and is the first transmitter to do this. Only one carrier wave, the radio energy that is used to carry the picture or sound electronic impulses developed by the microphone or television camera, is needed with Multiplex transmission. This wave carries both picture and sound to your receiver.

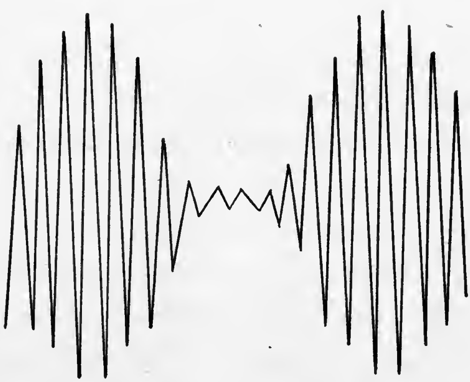
Sounds coming from our vocal cords produce words. The words which make up our conversations can be in any one of several languages. The same thoughts can be transmitted in various languages. We can think of the sounds we make as carrier waves for ideas. These sounds vary, depending upon the language we speak. Carrier waves vary, depending upon the method used for transmission. The same program can be transmitted and received by Amplitude Modulation, Frequency Modulation, Multiplex Transmission, and Pulse Time Modulation. In each case, a carrier wave is used to carry the program to your home. The difference is in the way the carrier wave is varied to carry the program. There are certain advantages and disadvantages to each system.

Amplitude Modulation was the first system used for commercial broadcasting. It is still used more than any other system. The basic principle of this system is quite simple. The carrier wave has a certain frequency which is developed by the transmitter. This is electrical energy which is fed to an antenna system which, in turn, radiates or sends out this electrical energy. The power or quantity of energy which is sent out is controlled by the transmitter. A ten-kilowatt transmitter is capable of delivering ten kilowatts of power to the antenna system or a ten-kilowatt carrier wave. In Amplitude Modulation, this power varies, and it is varied by the transmitter. The audio signal which is developed by the microphone is fed into the transmitter and varies the power output of the transmitter. This is called modulation and, as it varies in amplitude of power, this system is called Amplitude Modulation.



UNMODULATED CARRIER

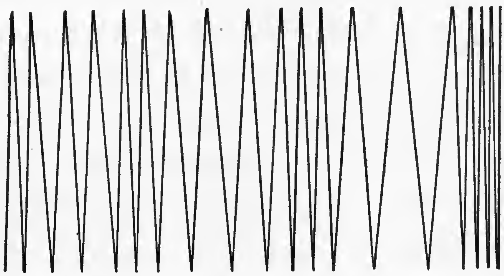
Frequency Modulation (F.M.) is the newest system used for commercial broadcasting. It is also used in conjunction with the lower frequency black and white television broadcasting, that is, when a separate carrier wave is used to transmit the sound. It is also being used with the new Multiplex system. With Frequency Modulation, the carrier wave does not vary in power. If a transmitting station is rated at 10 kilowatts, the transmitter always feeds the antenna sys-



AMPLITUDE-MODULATED CARRIER

tem with a 10-kilowatt carrier wave. The power of the signal remains constant. However, in the F.M. system the frequency, or number of cycles per second, of the carrier wave is varied. This is the reason it is called Frequency Modulation.

Frequency Modulation is becoming extremely popular because it eliminates static caused by lightning storms, elevator machinery, street cars, and other causes. Frequency



FREQUENCY-MODULATED CARRIER

Modulation also has another advantage—a more faithful reproduction of sound. Amplitude Modulation, with the present standards set up by the F.C.C., cannot transmit sounds above 10,000 cycles. This means that certain high-pitched sounds, such as cymbals make, cannot be accurately reproduced by Amplitude Modulation. Yet these high-pitched or higher audio frequency sounds are necessary for good sound reproduction. For example, music requires these higher frequencies for realistic reproduction of sound.

Frequency Modulation can reproduce sounds up to 15,000 cycles per second. This is as high-pitched a sound as most people can hear. Sounds higher than this become inaudible to the human ear. Music lovers prefer F.M. because of its more faithful reproduction and this is one of the reasons it is becoming so popular.

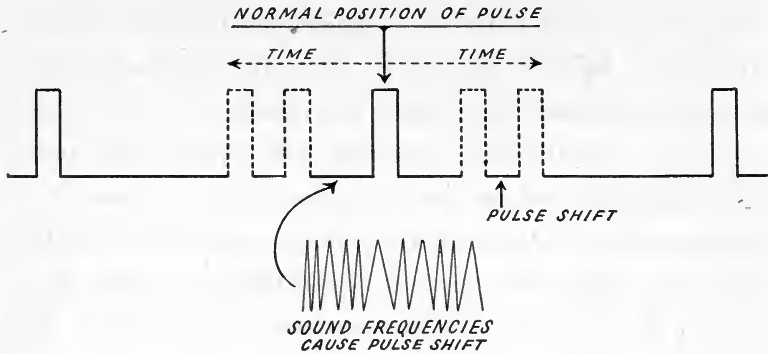
F.M. uses the high frequency carrier waves. The band of frequencies assigned to F.M. for commercial broadcasting by the F.C.C. is from 88 megacycles to 108 megacycles. This is not as high as the frequencies used for television. F.M., when it is used in conjunction with television, is also transmitted at higher frequencies. The F.M. carrier wave is similar in some respects to a television carrier wave. That is, it travels in a straight line similar to light and does not follow the curvature of the earth the way a lower frequency A.M. carrier wave does.

Static causes variations in the amplitude of the carrier wave, which would distort an A.M. transmitter, but as the amplitude of the carrier wave is not used to transmit the audio signal in F.M., static does not interfere. The F.M. receiver thus eliminates any variation in amplitude caused by natural or man-made static.

In Frequency Modulation, the transmitter carrier wave is varied in frequency by the audio or sound signal produced by the microphone. An F.M. station broadcasting on a frequency of 88 megacycles may vary this frequency as much as 75 kilocycles (75,000 cycles) plus or minus. That is, the frequency is constantly changing below and above 88 megacycles at a very rapid rate.

The carrier wave variation is dependent upon the loudness (amplitude) of the audio signal. The greater the amplitude of the audio signal, the greater the change in carrier wave frequency. Forgetting for a moment the amplifiers and other radio apparatus between the microphone and the transmitter, let us see what occurs as a person speaks into the microphone. If a person speaks softly into the microphone, the signal produced will only cause a slight variation in the transmitter carrier wave. It might cause a variation of 15 or 20 kilocycles each side of the 88-megacycle carrier wave. The carrier wave would swing from 88,015,000 to 87,985,000 cycles per second. If he raised his voice still higher, it might swing from 88,050,000 to 87,950,000 cycles. Extremely loud sounds may cause it to swing as much as 75,000 cycles each side of the carrier wave frequency. So the volume of the sound causes one variation in the transmitted signal. The type of sound causes another variation in the carrier wave signal.

As we now know from previous discussion, sounds have a frequency of their own. Let us see what happens to the carrier wave when a pure tone is picked up by the microphone. The carrier wave is varying back and forth, depending upon the loudness of this particular tone. The tone, let us say, is of an audible frequency of 5,000 cycles per second. This causes the carrier wave to swing back and forth at the rate of 5,000 cycles per second. If the tone were 8,000 cycles, then the carrier wave would swing back and forth at the rate



PULSE TIME MODULATION

of 8,000 cycles per second. If it were 12,000 cycles then it would change at the rate of 12,000 cycles per second.

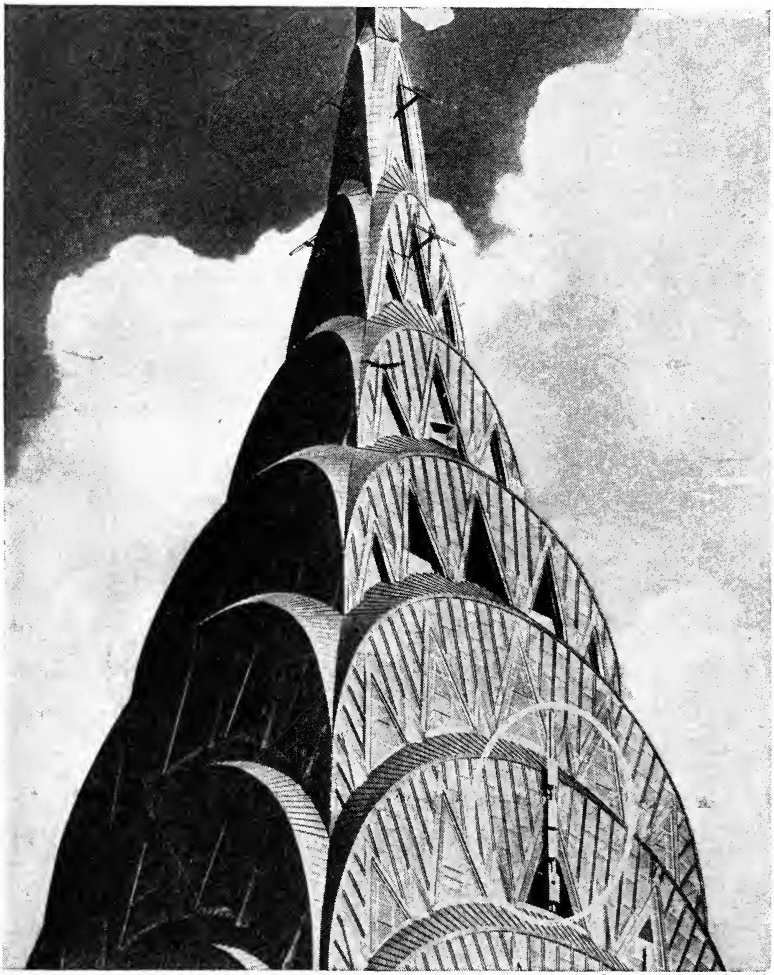
To sum up, the loudness of the sound determines the variation of carrier wave frequency, while the pure sound itself causes the rate of change in frequency.

Pulse Time Modulation, developed by Federal Telegraph and Radio Corporation, while it is one of the latest types of communication, is similar in some respects to one of the earliest types of radio transmission. The first type of radio communication used dots and dashes to transmit words, and the system most commonly used was known as the Morse Code. Each group of dots and dashes indicated a letter in the alphabet. For certain purposes, this system is still in use today. Pulse Time Modulation utilizes very short dashes to transmit speech or sound. You might say the system is similar to the Morse Code, except that the coding and decoding is done electronically. Also the dashes or dots are of such short duration and so rapid that the interruptions cannot be heard.

Pulse Time and the Multiplex system can both be used to transmit television sound and picture on the same carrier wave. Both systems operate by transmitting picture and sound intermittently. First, a group of picture impulses is transmitted, then a group of sound impulses is transmitted. This is done so rapidly that it is not possible to hear the interruptions. This is also true of the picture transmission—while the picture is transmitted intermittently the eye cannot detect the interruptions. So sound and picture are transmitted together in these new systems.

When combined with television, these new systems of sound transmission are called sound on picture or sound on sight, because sound and picture are transmitted together. When television pictures are transmitted, the picture is sent out line by line—each line being scanned left to right. When the scanning beam returns from the right hand edge of the screen to the left, no picture is transmitted. It is during this interval that the sound is transmitted. As the line scanning is approximately 39,000 lines per second the interruptions cannot be heard. The human ear is not capable of hearing interruptions above 16,000 or 18,000 thousand times per second, just as our sight cannot detect the interruptions of the picture transmissions.

Actually the mixing of the picture and sound is not done at the transmitter. This is done by electronic circuits after the signals have passed through the picture and sound con-



Courtesy of C.B.S.

COLORED TELEVISION SOUND ON PICTURE ANTENNA ON THE SIDE OF THE CHRYSLER BLDG., NEW YORK CITY. AT TOP OF PICTURE ARE BLACK AND WHITE SOUND AND PICTURE ANTENNAS trol desks in the television studios. These systems save separate transmission lines between the studios and the transmitter, as both signals can be sent over the same line.

This special electronic circuit converts the sound into short pulses which fit in between the picture pulses. First a picture impulse is sent out, then a sound impulse, then a picture impulse, etc. These two systems are meshed together to form an alternating chain of sound and picture pulses. In this form the signal is sent over a coaxial line to the transmitting station.

Pulse Time Modulation is somewhat similar to Frequency Modulation except that it relies on variation in pulses instead of frequency for transmitting sound frequencies.

In Pulse Time Modulation, the amplitude of the sound is transferred into variations in the time intervals between successive pulses. In this system marker impulses are sent out. The time interval between these marker pulses is constant and serves as a reference point. The sound impulses vary back and forth between the marker impulses. The amount of this variation is dependent upon the amplitude or volume of the signal.

If we could watch these impulses as we spoke into a microphone this is how they would act: If we spoke softly, the sound pulses would vary back and forth between the marker impulses only slightly. As we raised our voice the variation would increase. As the amplitude increases, the variation in time between pulses increases.

The speed with which these variations occur is determined by the frequency of the sound (audio) signal at that particular moment. If the sound were a pure tone of 1,000 cycles per second then the pulse would vary its position at the rate of 1,000 cycles per second.

Pulse Time Modulation can also be used for transmitting several conversations using the same carrier wave. That is, in place of transmitting a picture, several conversations or programs can be transmitted simultaneously. A standard broadcasting station could transmit several programs using a single transmitter and carrier wave. It is feasible to transmit eight or more conversations using this system. To do this, Pulse Time requires a specially designed transmitter and receiver and to date it has not been adopted for commercial broadcasting.

The method of transmission is similar to picture and sound transmission. If three radio programs were to be transmitted by this system, it would function in the following manner: first a short part of program #1 would be sent out, followed by a short pause. Secondly, a part of #2 program would be transmitted, followed by a short pause. Next program #3 would be sent out in a similar manner. Then the system repeats programs #1, 2 and 3. As these pulses each representing a different program can be transmitted in less than 125,000 part of a second, the interruptions cannot be heard.

The new C.B.S. color television transmitter uses the Multiplex system to transmit picture and sound. This transmitter was installed on the 71st floor of the Chrysler Building in New York City. The Multiplex system is really Frequency Modulation sent out in short bursts. F.M. is transmitted during the time the picture scanning beam is returning from left to right after it has completed a single line of the picture. Approximately 39,000 scanning lines are produced per second, so 39,000 bursts of F.M. are transmitted per second. The F.M. signal is the same type that is used for regular F.M. broadcasting. This was described earlier in the chapter.

The fundamental operating principle of this colored television transmitter is the same as a broadcasting or black and white television transmitter.

The transmitter generates a carrier wave and this carrier wave is combined with the impulses sent to the transmitting station by the studio cameras and microphones. The main difference in the new C.B.S. television transmitter is that it transmits picture and sound together. It also operates at a much higher carrier wave frequency than pre-war television. In fact, the war developed the technique of transmitting complicated signals at these high carrier wave frequencies.

The transmitter operates on a carrier wave frequency of 490 M.C. per second or 490,000,000 cycles per second. Frequencies as high as this are very difficult to amplify. However, the energy radiated is more efficient than in the lower frequencies used in broadcasting.

This unit is a 1,000 watt transmitter, but by the use of a newly developed antenna system it is the equivalent of a 20,000-watt transmitter. The antenna system is directional in a vertical plane, thereby concentrating its power where it will do the most good. As more energy is radiated in the direction of the receiver, the effective power is greater than in systems with less efficient antennas.

The color antenna consists of four units approximately 30″ long, stacked one above the other. The overall length of the entire antenna is about twenty feet. These units are mounted on an angle iron frame in front of the windows at the 71st floor level of the building. Two such antennas are used one on the south side of the building and one on the north side. This allows for complete coverage in all directions.

When the carrier wave is combined with the signals coming from the camera and microphone other frequencies are produced in the carrier wave. The combination of frequencies is called the band width of the television carrier. This system produces a band width of 10,000,000 cycles or 10 megacycles.

The transmitter equipment is housed in ten metal cabinets and weighs approximately 10,000 pounds. Metal doors on the front and back of the transmitter equipment make the electronic equipment accessible for maintenance. A separate rack in front of the equipment houses the indicating light and controls. The equipment was developed and designed by the Federal Telegraph and Radio Corporation for the Columbia

Broadcasting System.

When Multiplex or Pulse Time systems are used for television, the receiver separates the picture impulses from the sound. It breaks the chain of impulses into two separate signals. One of these signals contains all the necessary frequencies to reproduce the color picture. The other signal contains all the necessary frequencies to reproduce the sound.

As in all television receivers there are two sections to the receiver—one being video (picture) and the other being audio (sound). When these impulses are split up by the receiver, one signal feeds the audio section of the receiver and the other signal feeds the video section.

The public can expect to see and hear some of this new equipment within a short time. Before long, sound on picture receivers will be sold in the larger cities in the United States.

Chapter Sixteen

TELEVISION'S FUTURE

TELEVISION will expand and improve much faster than radio progressed when it made its debut. There are a number of reasons for this. At the time radio broadcasting came into use commercially, it was an entirely new medium of entertainment. It took years of work to build up its real entertainment value. Also, its equipment, such as microphones and transmitters, was poor, and receiving equipment was inadequate. Most early radio sets operated from batteries and a great many of these sets were only equipped with headphones. A good many sets were put together by amateurs, so that the quality of reception was poor. The main interest in radio at that time was the idea of being able to receive a program through the air, which seemed miraculous. People owning sets would call in their neighbors and sit around a receiver passing the headphones from one person to another. Listeners tried to receive stations at as many distant points as possible. They were thrilled if they were in New York and could pick up a program in Washington or Albany. Some men stayed up all night trying to receive distant stations. The programs consisted mainly of recordings of musical selections. It took years to develop good transmitting and receiving equipment and to produce programs with high entertainment value.

Television today is in a much better position. Much has been learned in building and designing good commercial electronic equipment. Then too, the manufacturers of this equipment have been careful to develop it to a high enough degree for public acceptance before putting it on the market. As we mentioned previously, research work has been carried out to improve programs rapidly. At the present time additional television studios are being built and it is expected that within the next year or two television studios will be operating in almost every major city in the United States. While television will adopt higher standards when the new ultra-high frequency black and white system and color system are put into commercial use, this transition will not retard the progress of television. It may be similar to the situation in broadcasting today where A.M. and F.M. stations are both operating. Both the old and new standards of television may be used in telecasting simultaneously. People who purchase the new type of receivers will have higher definition in their sets and will receive full colored pictures. Of course, a great deal hinges on the actions of the Federal Communications Commission. They have to approve this new system for commercial use and may do so at any time. Many people have wondered if television will eventually eliminate standard broadcasting. Most people in the business do not believe this will happen. Motion pictures did not eliminate the legitimate stage, nor did radio eliminate the phonograph. Momentarily, they had an effect on the other mediums of entertainment, but within a short time the others came back to take their rightful place in the entertainment field. Probably, when most homes are equipped with television sets, radio broadcasting listeners will fall off. However, there are many hours during the day and night when people will be working and will not have time to look at a television program. They will still want to listen to music and other forms of radio entertainment. Television will undoubtedly have an important place in the entertainment field, but it will not do away with radio broadcasting.

Television will also be put to many new uses. Theater television is one of these. At first probably not every family will be able to afford a television receiver. Therefore, many people will be willing to pay to see sports events and other forms of television entertainment in theaters. It might be quite popular in the case of major prize fights, for instance, or golf, horse racing and other sports. The advantage of being able to see the program on a full size motion picture screen would attract many.

In this type of operation the program would be picked up by a standard television pickup camera, and transmitted directly to the theater by link transmission or sent over coaxial lines. If the theater were located in Chicago and the event was in New York the program could be transmitted to the theater in any one of several ways. It could be sent by relay transmitters from city to city, retransmitted by one of the major telecasters in Chicago, and then picked up on receiving antenna located on the roof of the theater. It could be sent over coaxial lines from the pickup point directly to the theater. This latter system would eliminate static which tends to distort the picture. Or it could be relayed by a stratovision plane.

The theater equipment would be quite simple. It would amount to a very expensive television receiver and a special theater projection unit. A television mixer would probably be used to correct the defects in transmission. This mixer would be similar to the type used in the television control rooms for telecasting purposes. It would have brilliant controls, shading controls, horizontal and vertical controls for re-aligning the television picture. The technician could be seated near the projector in order to make necessary adjustments while watching the show. This system would allow people all over the United States to see any major event as it occurred. For example, the World Series could be telecast to all large cities and shown at motion picture theaters. This system is not only practical in theory, but it would attract thousands of people interested in sports.

Another commercial use for television is in department stores. This system was developed by the General Electric Company. It is a merchandising system whereby a large department store can visually show its wares. This equipment is being installed in some of the larger stores at present. It is designed so programs can be shown or picked up at almost any locality in the department store.

It requires only a small studio and control room. No transmitter is necessary as the program can be sent to other parts of the store by coaxial line. Also pickup points other than the studio can be utilized. These points would be connected to the control room by coaxial line. The program then goes to the control room where it is monitored or checked before traveling to the various receiver outlets.

This allows the store to televise any special merchandising program to all other parts of the store. Receivers can be placed in the store windows so people passing by can see any special sales which the store is featuring. This system aids the shopper and the store, as the shopper can see the special sales on other floors and the store can show its special merchandise to more customers.

The equipment would consist of portable cameras, microphone booms and lights. Special portable light stands have been designed which can be plugged into television lighting outlets at each location. This system allows merchandising programs to be picked up at any counter or location in the store. The studio would be used for more elaborate sales programs. A film projector and a film pickup camera are part of the studio equipment and are used for entertainment and special features.

It is also expected that television will be used in manufacturing plants and other places, especially in the testing of equipment when testing conditions are hazardous. As an example, if a high speed jet engine were to be put to test in a room where it might explode, television could be utilized to watch the machine in action. A television camera could be set up close to the engine so that it would pick up the engine while it was in operation. A receiving set could be placed in another part of the plant where the operation of the engine could be viewed.

Television can also be used to visually check plant operations. Large manufacturing plants are usually spread over a considerable area making it difficult for the plant managers and officers to supervise all operations. By using television the problem can be simplified considerably. Television cameras could be set up with super-sensitive pickup tubes at various locations in the plant. As an example, cameras could be set up at the main assembly line, the sub assembly lines and parts of the plant which fabricate some of the smaller units for the sub assemblies. All these cameras would transmit the picture to a single location. This might be the plant manager's office. In this way, he could watch all operations of his plant simultaneously. This would enable him to immediately catch difficulties occurring in almost any section of the plant which normally he would not know about. He could visually check each operation making mental notes of bottlenecks or inefficiencies which occur. It would then be possible for him to devise means of correcting these difficulties. It is easily seen that television used in this manner might be the means of much smoother operations in the plant. It is quite possible that this could lead to a reduction in manufacturing costs. By the use of systems of this type, many manufacturing difficulties may be overcome.

To date, the greatest known commercial use of television was in the testing of the atomic bomb at Operations Crossroads in the Pacific. The large broadcasting companies sent their engineering personnel to help in the telecasting of these tests for the Navy. The first test of the atom bomb above water carried the code word Baker. In the Baker test, the television receiving equipment was set up on the U.S.S. *Mount McKinley*. Pickup cameras were set up in an observation plane circling the target area The plane was equipped with a television transmitter and antenna system for relaying the action back to the U.S.S. *Mount McKinley*. This allowed all important Navy personnel of the mother ship to visually check the entire operation. By transmitting the action in this manner, it was immediately known, for instance, that the palm trees of Bikini Atoll were still standing after the atomic bomb exploded. It was also possible for the officers gathered around the receivers to study the cloud formation caused by the atomic explosion.

The second atom bomb test carried the code word Able and it was conducted on June 30, 1946. In this test the bomb was exploded under water. This time the television receiving equipment was installed on the U.S.S. *Appalachian.* As before, a plane was used to telecast the action of the bomb. The U.S.S. *Appalachian* was located eighteen miles away from the target area. This placed the ship below the horizon, so the action of the bomb could not be watched by telescope or field glasses. Because of television, however, it was possible for the officers to watch this test as if they were viewing it from a plane flying at high altitude. It was possible for them to tell which ships were sunk at the first action of the bomb. Also, they could see the terrific water spout which was caused by this under-water explosion. This gave them very valuable first-hand information.

Undoubtedly many other important uses for television will be discovered. It will become part of our daily lives just as telephone, automobile, airplane and radio have. It will mean jobs for thousands of men. It will provide entertainment for millions of people. It will educate many and in some cases even save lives. Television engineers have broken the surface of a new field with such great possibilities that no one can predict all of its uses or what it may lead to in the near future.

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