Television Manual

AMERICAN TELEVISION INSTITUTE OF TECHNOLOGY

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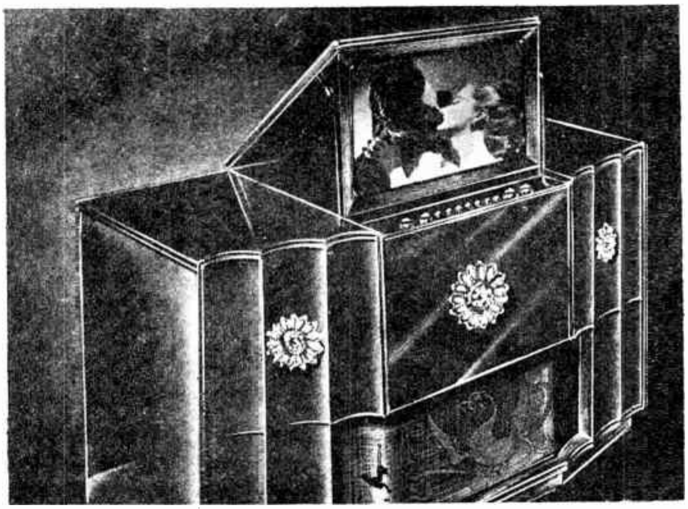
CHAPTER I

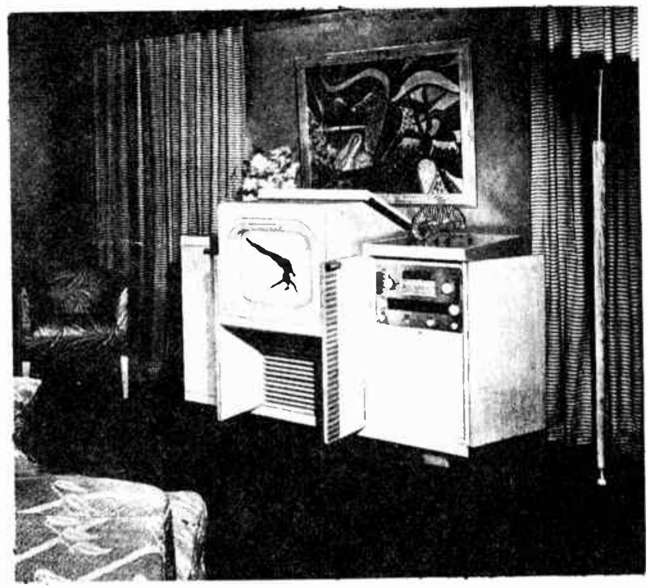
INTRODUCTION

Television, as a means of entertainment and a source of income is rapidly becoming as important as the present sound broadcasting. To many men who have seen television grow and who have been instrumental in this growth, this is regarded as a natural development. A medium which utilizes two senses (sight and sound) is certain to offer more to the observer than if one sense alone is utilized.

TELECON



DUMONT



FARNSWORTH

Fig. 1.
Television receivers in current production

Television receivers are available in either console or table models. Several units of each are illustrated in Fig. 1. The larger receivers, which retail up to $2,500 (with an average price of around $1,200) possess a larger receiving screen and better designed circuits. In this, both the present sound receivers and the television receivers are comparable. The smaller television sets, the table models, market at an average price of $250. In general their screens are no larger than 10 inches in diameter and many are designed solely for television reception. Almost all the larger models have provision for receiving the standard A.M. frequencies while many also include F-M and short-wave. As we shall see when television receiver circuits are analyzed, the reception of the other frequencies involves merely the addition of a simple tuner for each. These tuners, in conjunction with the circuits already existing in the television set itself, provide a complete unit. Not only does this represent a saving for the consumer, but it also makes for a neater and more compact arrangement.

In approaching a television receiver, we find our attention immediately directed toward the viewing screen. Everything within the receiver is designed with but one idea, to make the image as faithful a reproduction of the original scene as possible. It would seem therefore, that the best place to begin a study of television is with the image itself. From the observers viewpoint, the screen should possess the following properties:

1. Be capable of reproducing the scene with sufficient detail to give the appearance of a smooth, continuous texture.

2. As with the movies, no flicker must be observable.

3. The image should be bright enough to permit viewing without any dimming of the light normally used to illuminate a room.

4. A large size screen that will permit comfortable viewing by 7 to 10 people.

5. A contrast range of the screen which is sufficiently wide to produce an image which will not have a dull or flat appearance.

The foregoing features are readily obtainable with present-day equipment. However, in order to fully appreciate some of the problems involved in obtaining these properties, let us examine carefully the present form of the television receiving and transmitting equipment.

Television Cameras

At the television broadcasting studio, a camera focuses the light from the scene onto a photosensitive plate. The plate converts the light into an equivalent electrical charge from which a series of electrical pulses can be obtained. These pulses, in conjunction with the proper synchronizing voltages constitute the video signal. The total video signal, after it has been sufficiently amplified, is made to modulate a carrier in the same fashion as a sound wave. This, then, is the television signal as it reaches the receiver. A block diagram of a television receiver is shown in Fig. 2. In many respects it may be compared to the sound superheterodyne. Thus, if we look across the center of the diagram, we see the usual r.f., mixer oscillator, and i.f. stages, detector and video amplifiers.

However, there are many additional stages which are specifically required because of the difference in audio and video signals. Into this category fall such stages as the pulse clipper, pulse separator, and horizontal and vertical saw-tooth generators. In the main, these additional circuits deal with the synchronizing pulses and their function of keeping the receiver in step with the received signal.

In sound broadcasting, the microphone receives the spoken sound and converts it into an equivalent electrical impulse. The problem, in television, is to take the scenes that we desire to transmit and likewise transform it into an equivalent electrical signal. Basically, we require some device which will act as an agent between the incoming light rays and the resultant electrical currents. This is the function of the television camera. See Fig. 3. The light rays

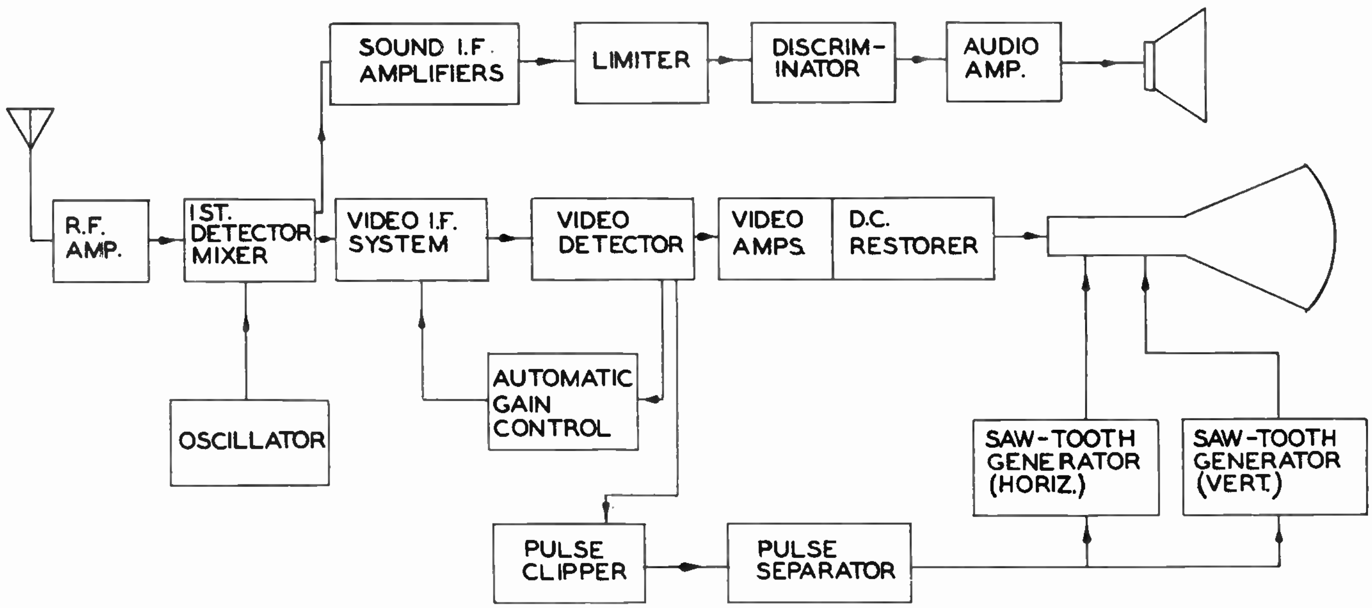


Fig. 2.

from the scene are focused by the camera lens onto a photosensitive surface, known as a mosaic. The mosaic, which is placed inside the evacuated camera tube, consists of a mica plate with one face coated with a photosensitive layer of a caesium-silver compound. This side is turned toward the light. The rays, reaching the mosaic, impart sufficient energy to the sensitive coating to force the emission of secondary electrons. Furthermore, the number of electrons which are given off are directly dependent upon the intensity of the light rays at any particular area. Thus, the resulting charge distribution on the moxaic plate will be identical in all respects to the light distribution throughout the scene.

The construction of the mosaic plate is such that each globule of caesium-silver compound does not come into contact with any other globule, Hence, when one globule loses several electrons due to the incident light, we may consider, in this simplified analysis, that it does not, in in any way, influence the charge of any other globule. On the reverse side of the mosaic there is one continuous conducting sheet. From this sheet, connection is made to the camera load resistor. The voltage developed across this resistor (R in Fig. 3) due to the pulses of current flowing through it represents the video signal.

Returning to the mosaic, we see that due to its construction it consists essentially of a series of condensers with mica as the dielectric. All the condensers have one common plate, the backside of the mosaic. The fact that one plate is common to all does not, in any way, invalidate the condenser action.

The first step in the conversion of the light rays into equivalent electrical currents has now been accomplished. There is a charge distribution which is equivalent to the incident light rays. There remains the second and final step--that of converting the various charges into corresponding electrical currents.

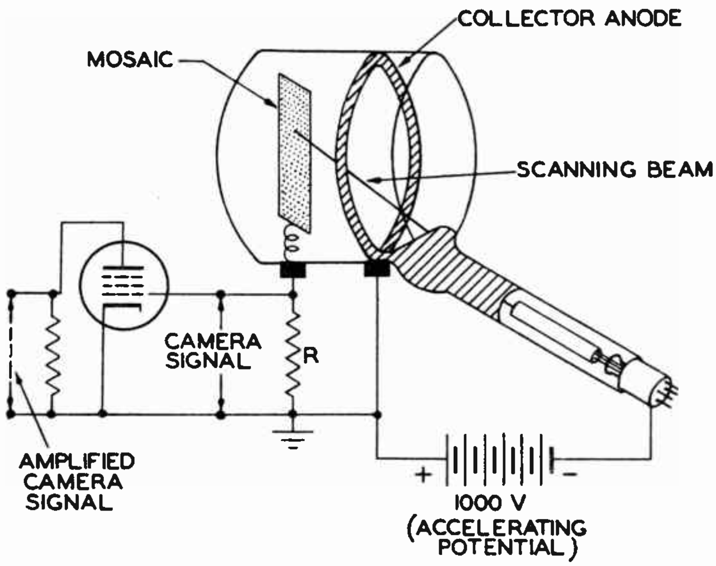


Fig. 3.

It is not only necessary to convert the charge into currents, but, some regular method must also be decided upon with which to scan the image. In transmitting a scene it would be highly impractical to send all the image charges simultaneously because this would involve the use of many circuits. However, if we dissect the image in a series of narrow strips and then send the information in each strip in an orderly manner, then we can utilize but one circuit. At the transmitter the scene is broken down in the proper number of strips or lines and then reformed at the receiver.

In order to convert the mosaic charges into currents, a narrow electron beam is formed within the tube and directed at the mosaic plate. The beam starts at the upper left-hand corner of the mosaic and, under the influence of deflecting voltages, slowly travels horizontally across the plate. At each globule, the beam releases enough electrons to make up for the deficiency caused by the incident light rays. This neutralization releases an equivalent charge on the reverse side of the mosaic and flow of current takes place. The current passes throught the load resistor, R, and develops a voltage. This is the video voltage and it is fed to a series of amplifiers to bring it to the proper amplitude.

The beam continues to move across the mosaic until it reaches the extreme right-hand side. This completes the scanning of one line. In order to place the beam in position for the next line, it is quickly brought back to the left hand side of the mosaic again. Once in position, the beam starts its slow motion toward the right. This sequence is repeated for as many times as the image is broken down into, which, under present television standards, is 525.

It is readily seen that a close synchronization must be maintained between the motion of the scanning beam in the camera tube with the motion of the electron beam in the receiver image tube. Unless this is done it may very well happen that the bottom part of the scene will appear at the top of the receiver screen. (This may be observed in any receiver by adjusting the hold control until the receiver is no longer in synchronization with the incoming signal.) To indicate to the receiving system the precise instants when the beam must swing over to the left-hand side of the screen and when it must return from the bottom of the screen to the top, synchronizing pulses are inserted into the video signal. With these the transmitter and receiver can be locked in with each other. As long as the synchronization is maintained, both pictures will be identical.

Image Scanning and Flicker: The process of scanning was touched on briefly because it was more important to understand the general overall operation, The scanning sequence, however, is not as simple as described for several reasons. First, there is the problem of flicker. Whenever a set of related films are shown on a screen, the human eye is able to correlate them and make their action appear continuous if the images follow each other fairly rapidly. This is what happens in the movie theatre. Each individual film is itself stationary. However, by showing all the related strips at a fairly rapid rate, it is possible to have the observer believe that a continuous action is occuring. If the rate of presentation is steadily decreased, a point is soon reached where the image from each film frame diminishes sufficiently in our mind to make us aware that the action is not continuous. At this point we say that flicker is evident. For optimum results in entertainment, no flicker must be discernible.

Among other things, the bandwidth that any television signal requires is a function of the number of complete pictures (or frames) sent in one second. We shall see, as we become more conversant with television, that anything which reduces the number of frames per second, without introducing flicker, is desirable. Hence, if we could somehow find some other system which would permit us to transmit the full 525 lines in fewer frames than 50, a considerable and desirable saving in frequency space could be achieved. Such a method has been found and is known as "interlaced scanning". Why this method is successful is due to the "persistence of vision" phenomena of the human eye.

Whenever a light impulse reaches the eye, the impression that results does not immediately disappear. How long the sensation remains, after the light itself has vanished, is a function of the surrounding illumination and the intensity of the impulse. However, the important aspect is the retention of the light image in our mind's eye after it has ceased to exist. If a series of separate pulses of light reach our eyes sufficiently fast, the result, to us, is the same as that produced by a steady unwavering light. In other words, we possess the ability (if we wish to call it that) of holding the sensation produced by one impulse for some small length of time after its energy has ceased to exist.

In the movies, the presentation of a picture is accomplished by projecting the image of each individual frame onto the screen. Here again, a rate of 50 frames per second would be required. However, by a clever device, only 24 frames are projected each second, yet no flicker is evident. The method is quite simple. Instead of showing each frame once, it is shown twice. This is done by holding the frame in place while a shutter passes over it, monentarily blocking it off from the screen. After the shutter passes, the frame is once again projected on the screen. Thus, while only 24 frames are actually used, to the observer they appear as 48 because of the shutter action. At this rate there is no flicker.

In television, we can accomplish essentially the same effect by interlaced scanning. Instead of scanning all the lines of an image successively, the image is first scanned using every other line. After all the odd lines, for example, have been scanned, the remaining ones (in this instance the even ones) are scanned. Thus, in a total of 525 lines, 262 1/2 are sent one time and the remaining 262 1/2 are sent the next time. Each set (which is known as a field) requires 1/60 of a second, or both fields (which combine to form a frame) need 2/60 of a second or 1/30 of a second. Hence, 30 complete frames are scanned in one second. To the observer, however, there is the equivalent of 60 frames per second. Flicker is totally absent.

We are now in a position to reconstruct the entire scanning procedure. The scanning beam starts at the upper left-hand corner and travels horizontally until the end of the line is reached. At this moment a blanking pulse appears which cuts off the beam from reaching the screen. During this blanking interval, a synchronizing pulse triggers the vertical deflection oscillator and the beam is rapidly shifted into position for the next odd line. Note that the intervening even line is omitted for the time being. The blanking voltage is now removed and the scanning process starts anew. This sequence is repeated over and over again until every odd line has been scanned. The beam is now at the botttom of the image.

At this point a longer blanking pulse is injected and the beam brought back to the top of the image. Note that because each field contains 262 1/2 lines that the beam must be brought back to the center of the screen, one line above the first line of the previous field. This is shown in Fig. 4. From this position the beam then scans every other even line, or those lines which were not scanned on the previous run. The use of the words odd and even is arbitrary. They merely indicate the interlaced pattern. The important point to remember is that every other line is scanned during any one field.

There is one point which has been omitted. This concerns the fact that in traveling from left to right, the beam does so at a slight angle. This is also indicated in Fig. 4. The reason for this is quite simple. By having the scanning beam travel at an angle from left to right, it can be snapped back straight across during the retrace period and thus shifted readily into position at the start of the next line. The retrace path is indicated by the broken dashed line.

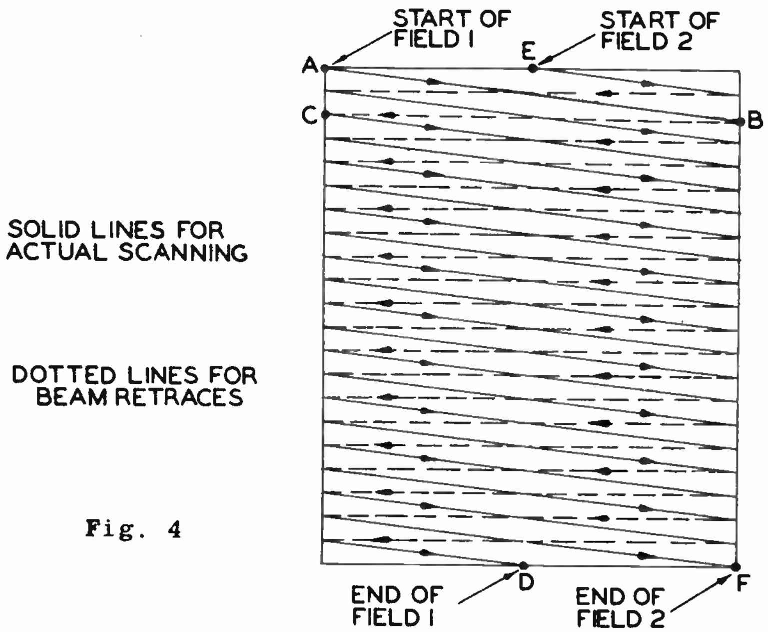


Fig. 4

In later lessons, the precise form of the synchronizing pulses will be studied, together with the method employed to separate the vertical and horizontal pulses.

The Video Signal

The method of combining the camera detail, the synchronizing pulses and the blanking voltage is shown is Fig. 5. Two complete lines are indicated. Note that the camera voltage occupies 75% of the maximum possible amplitude while the blanking and synchronizing pulses require the remaining 25%. At the end of each line, the voltage rises sharply to the blanking level. This cuts-off the electron beam. During this period the synchronizing pulse is active and swings the beam into position for the following line. Once accomplished, the blanking voltage relinquishes control and the camera detail again becomes active.

The camera signal ranges from white to black, the latter naturally occuring at the level of the blanking voltage. Black means the absence of all light and this, in turn, requires beam cut-off. Hence, the blanking level is known as the black level. Since the synchronizing voltage extends beyond this so-called black level, it is labeled as the blacker-than-black region. In terms of the image, this has no significance.

The signal, as shown in Fig. 5, is in the same form which it uses to modulate the carrier. The synchronizing pulses possess the most positive potential, while the brightest portions of the image are represented by the most negative voltages. If we consider this signal, we note that all the relative values are reversed. In other words, if the signal, in this form, were applied to the grid of the cathode-ray tube, a reversed image (like a photographic negative) would be obtained. At the grid, the brightest sections of the image must be represented by the most positive voltages. The black region is obtained by current cut-off or driving the grid sufficiently negative to stop the electron beam from reaching the screen. The video signal,

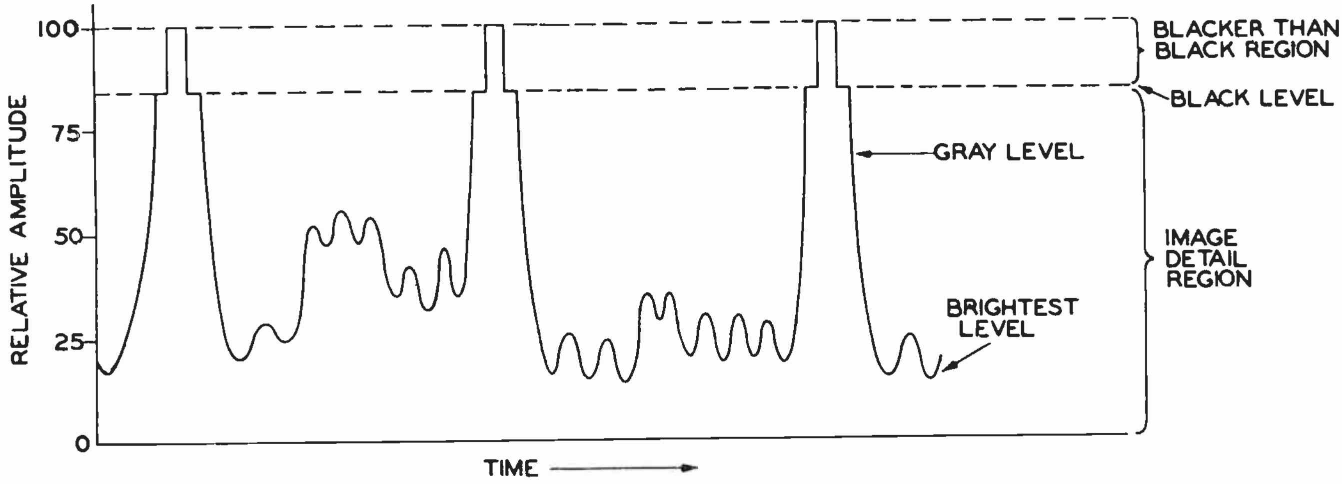


Fig. 5.

in the form shown in Fig. 5, because of the reversal of values, is said to be in the negative picture phase. The carrier is modulated by the video signal in this form and is transmitted over the air. In the United States, all television transmission is in this negative phase. The reasons for this particular choice will be investigated in a later section. In England, the positive picture phase is used for modulating the carrier and thus they have positive picture transmission.

Audio and Video Modulation: Within the past 10 years frequency modulation, as a method of transmission has become increasingly popular. It has been found, as far as sound is concerned, that F-M results in superior reception and greater freedom from noise. Hence, F-M is the mode of transmission for the audio portion of the television signal.

Due to these same characteristics, it was at first believed that F-M for the video signal would likewise be desirable. This might have been true if the reflection of the higher radio waves from surrounding objects (such as buildings, mountains, hills, etc.) did not occur as frequently as they do. The radio signal, when it leaves the transmitting antenna, does not always reach the receiving antenna by the most direct route. This is especially true in cities. The wave generally hits some steel structure and bounces (or reflects) off in another direction. Hence, it is a common occurence for the same signal to reach the television receiving antenna by several routes. Multipath reception, it has been experimentally determined, proves far more troublesome when F-M is used. This not only affects the general appearance of the image, but it also interferes with the synchronizing action. Hence, A-M is used for the video portion of the television signal, while F-M is reserved for the audio section.

It may be wondered why multipath reception of an F-M signal is so much more troublesome with the video than the audio signal. To understand this, let us consider the effect of multipath reception on both the video and the audio signals. When the radio waves leave the transmitting tower and, through reflection, arrive at the antenna from several different paths, it causes the formation of voltages which are alike but which differ in phase from each other. The latter difference, of course, arises from the varying lengths of each path between the transmitter and receiver. If the paths taken by two signals in reaching an antenna differ by half a wavelength, the two voltages will be out-of-phase and cancel completely. At other path length differences, less cancellation will occur. Since the human ear is relatively insensitive to moderate phase differences between voltages, it is feasible to employ F-M for the sound channel. Let us determine, however, what the effect is on the video signal.

The video voltages are traced out on the cathode-ray tube screen in the order of their arrival. But if the same signal arrives at the receiver antenna at slightly different moments (due to path difference) the visual result is two identical images slightly displaced from each other. This phenomenon is known as "ghosts" and if pronounced can completely ruin the observer's enjoyment of the broadcast. Since F-M produces more distorted ghosts than A-M, it was decided to use the latter as the method for transmitting the video signals.

Frequency Allocations

Until quite recently, there were many sections of the frequency spectrum which were not definitely assigned by the Federal Communications Commission. Realizing that such uncertainty was retarding development of equipment for these frequencies, the F.C.C. has allocated all frequencies up to 30,000 MC to specific services. These are shown in Table I. Of particular interest are the television frequencies. Between 44 to 88 mc., there are six channels, each six megacycles wide. Since only black and white television can, under the present systems, be transmitted in this bandwidth, the six channels are being used exclusively for this form of image. Seven additional channels are situated between 174 and 216 mc. Provision is made for the experimental color television transmissions in the frequencies from 480-920 mc. No fixed channels are designated here in order to permit complete freedom in experimentation.

TABLE I.

Frequency in Mc.	United States Allocation
25.015-27.185	Government and non-gov. fixed and mobile (*) (1)
27.185-27.455	Scientific, industrial and medical (**)
27.455-28	Government and non-gov. fixed and mobile (*) (1)
28-29.700	Amateur
29.700-30	Government and non-gov. fixed and mobile (*) (1)
30-30.5	Government (2)
30.5-32	Non-government fixed and mobile (2) (3)
32-33	Government (2)
33-34	Non-government fixed and mobile (2) (3)
34-35	Government (2)
35-36	Non-government fixed and mobile (2) (3)
36-37	Government (2)
37-38	Non-government fixed and mobile (2) (3)
38-39	Government (2)
39-40	Non-government fixed and mobile (2) (3)
40-40.96	Government (2)
40.96-41	Scientific, industrial and medical
42-44	Non-government fixed and mobile (2) (4)
44-50	Television
50-54	Amateur
54-60	Television
60-66	Television
66-72	Television
72-76	Relay
76-82	Television
82-88	Television

TABLE I (continued)

Frequency in Mc	United States Allocation
88-108	Frequency Modulation
108-112	Government
112-118	Government
118-122	Airport control
122-132	Aero mobile primarily non-government
132-144	Government
144-148	Amateur
148-152	Government
152-162	Non-government fixed and mobile (5)
162-174	Government
174-180	Television and government
180-186	Television and government
186-192	Television fixed and mobile (6)
192-198	Television fixed and mobile (6)
198-204	Television fixed and mobile (6)
204-210	Television fixed and mobile (6)
210-216	Television fixed and mobile (6)
216-220	Government
220.225	Amateur
225-328.6	Military, and civil aviation channels
328.6-335.4	Glide path air navigation aids
335.4-400	Military, and civil aviation channels
400-420	Government, including radiosonde
420-450	Amateur and air navigation (7)
450-460	Non-government fixed and mobile (8)
460-470	Citizen's radio
470-480	Facsimile broadcasting
480-920	Television
920-940	Experimental broadcast services
940-960	Fixed and experimental broadcasting (9)
960-1145	Navigation aids
1145-1245	Amateur
1245-1325	Television relay
1325-1375	Non-government fixed and mobile including aero.
1375-1600	Government
1600-1700	Air navigation aids
1700-1750	Meterorological
1750-2100	Non-government fixed and mobile
2100-2300	Government
2300-2450	Amateur
2450-2700	Non-government fixed and mobile
2700-2900	Meterorological and air navigation aids
2900-3700	Naviagtion aids
3700-3900	Air navigation aids
3900-4400	Non-government fixed and mobile
4400-5000	Government
5000-5250	Instrument landing air navigation aids
5250-5650	Amateur

TABLE I (continued)

Frequency in Mc.	United States Allocation
5650-7050	Non-government fixed and mobile
7050-8500	Government
8500-10,000	Government
10,000-10,500	Amateur
10,500-13,000	Non-government fixed and mobile
13,000-16,000	Government
16,000-18,000	Non-government fixed and mobile
18,000-21,000	Government
21,000-22,000	Amateur
22,000-26,000	Government
26,000-30,000	Non-government fixed and mobile
30,000-up	Experimental

Notes

(*) Power to be limited internationally to 500 watts peak.

(**) All equipment to be adjusted and maintained as closely as possible to 27.320 Mc.

(1) On the basis of an average channel width of 25 kc. in the band between 25 and 28 Mc. there will be 24 relay broadcast and geophysical channels, 12 channels for power, petroleum and other industries requiring similar radio service, 10 provisional and experimental channels, 7 aeronautical channels primarily for flight tests and flying schools, and 6 relay press and motion picture channels.

(2) No change proposed in existing services between 30 and 44 Mc. outside the continental United States.

(3) On the basis of an initial channel width of 40 kc. in the band between 30 and 40 Mc. there will be 36 police channels, 29 channels for forestry and conservation (6 of them shared with maritime mobile and another 6 shared with urban transit), 20 channels for general highway mobile (for all types of service such as marine, land vehicles, aircraft, etc.; pending final determination of the best method of operation these channels will be assigned on an experimental basis, with 12 channels assigned to development on a common carrier basis, 4 going to trucks and 4 going to buses, except in those cases where it is shown that a different distribution is more desirable,) 15 channels for fire, 11 for govern mental use, 7 for power, petroleum and other industries requiring similar radio service, 6 for special emergency, 5 for maritime mobile and geophysical, 5 for urban transit, provisional and experimental, 2 for provisional and experimental, and 2 for provisional and experimental with antenna input limited to 5 watts peak.

(4) On the basis of an average channel width initially of 40 kc. in the band between 42 and 44 Mc. there will be 24 police channels, 20 general highway mobile channels (subject to the same division as general highway mobile service in note 3), 5 maritime mobile and geophysical channels, and 1 provisional and experimental channel.

(5) On the basis of an average channel width of 60 kc, in the band between 152 and 162 Mc. there will be 60 channels for railroads, 36 channels for police, 24 channels for urban mobile (subject to the same division as general highway mobile service in notes 3 and 4) and for rural subscriber and short-distance toll telephone, 12 for fire, 12 for relay broadcast, 8 for maritime mobile, 6 for power, petroleum, and other industries requiring similar radio service, 4 for relay press, forestry, conservation and geophysical and 4 for provisional and experimental. Services now operating between 156 and 162 Mc. may continue temporarily on a non-interfering basis.

(6) Provision may be made for the operation of non-governmental fixed and mobile services (such as police control and relay circuits, point-to-point, marine control circuits, forestry fixed circuits, rural telephone, broadcast studio-to-transmitter links, railroad terminal and yard operations) upon proper showing of need, and that such channels may be shared on a mutually non-interfering basis.

(7) To be used temporarily for special air navigation aids. Band to be exclusively amateur when no longer required for such aids, with amateur peak power meanwhile being limited to 50 watts.

(8) To be temporarily used for special air navigation aids and reserved for non-government services when no longer required for such aids.

(9) May be used by low-power fixed point-to-point stations for such services as studio-transmitter links, control circuits, and police fixed facsimile circuits.

CHAPTER II

MECHANICAL SCANNING SYSTEMS

In the past few years we have heard less and less about mechanical television systems and more and more about cathode-ray tubes. However, in the past year or so, color television has jumped to the forefront and has received considerable publicity. Color television, in one of its present forms, is partly electronic and partly mechanical in nature. For this reason, and also because mechanical scanning systems are the oldest and simplest television systems, we shall discuss them in this text.

The first idea for television transmission and reception was the nerve system. The idea was to have a single photo cell for each element of the picture to be transmitted, to have a wire going to an amplifier, and thence to a light source. An amplifier, a light source, and a wire is needed for each element of the pictures. Since this would require hundreds of thousands of amplifiers, hundreds of thousands of wires, and hundreds of thousands of light sources, the idea is obviously impractical. The oldest practical system of television can therefore be stated to be the aperture disc system invented by Paul Nipkow over 52 years ago. The main difference between his system and the previous ones was the idea of scanning. Instead of sending all of the signals corresponding to all of the picture elements at one time, the picture was to be dissected into its elements and the elements were to be transmitted in turn and then reassembled at the receiver. This breaking down and reassembling of the picture must occur so rapidly that the eye will not know it is happening. That is, the picture period must be less than the period of persistance of vision of the eye. With this system, only one amplifier, one wire, and one light source need be used.

It is obvious that if the signal which is transmitted is to produce an element of the image at the receiver corresponding to the same element at the studio, the process of dissecting and the process of integrating must be synchronous or in step with each other. If this were not the case, the elements of the image at the receiver could easily be displaced from their proper positions. Up to the present time the scanning system is the only one used in commercial television and apparently only two systems of television have ever been invented which do not use scanning. One of these systems is the nerve system described above. For this reason, the invention of Paul Nipkow is still of the greatest importance, even though the aperture disc which he used to perform the scanning function has been largely replaced by other and more efficient scanning means.

Since the invention of the scanning disc, many thousands of arrangements have been contrived in an effort to increase the light efficiency of the television system. Most of these have been found to be of little practical value and there was probably no higher mortality in the realm of invention than in the field of television scanning systems. Through various combinations of mirrors, prisms, and lenses, it can be truthfully said that the greatest advancement of all occurred when the idea of projecting a whole line of the image at one time was developed. This is accomplished in the Scophony light valve. This light valve is used in conjunction with tiny mirror drums which are less than an inch in diameter and are incorporated in what is known commercially as a beam converter. Probably the first demonstration of the superiority of high speed mirror drums was incorporated in that television device known as the Mihaly-Traub system which uses a combination of a mirror drum and a ring of stationary mirrors. By the use of such systems, picture rasters 4 by 5 feet in size and so brilliant that they can be used in small cinemas have been developed. Whether they will find application in the present black and white system or the color television yet to come remains to be seen.

THE APERTURE DISC

The aperture disc was invented by Paul Nipkow in 1884 and in spite of its comparative antiquity, its efficiency is greater than most other systems for the same number of lines. It is also more economical to produce and these factors made it one of the most popular forms of mechanical scanning. Since the invention of the aperture disc, there have been numerous scanning devices invented, but its efficiency is only exceeded by a special mirrored system and then when the speed of the motor is extremely high.

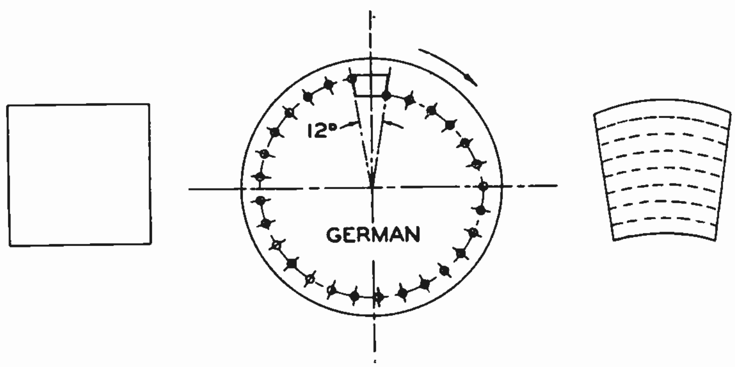


Fig. 1.

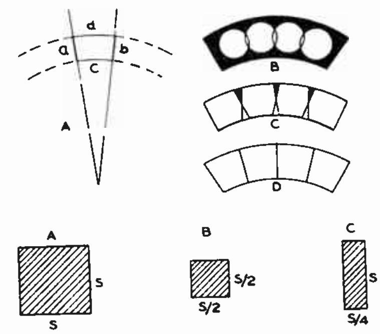


Fig. 2.

The scanning of the picture apperture is accomplished in the following manner. The hole at the top of the picture aperture passes across the top of the aperture so that it sweeps out a line of the picture. See Fig. 1. The holes are spaced exactly the same distance apart as the aperture is wide, so that one hole is uncovered just as the other disappears on the opposite side. This hole sweeps out its line in turn and so down the disc. When the last hole of the disc disappears, the top hole repeats its former line and the cycle continues. If the disc were stopped at any one point, then the light would be shining through one hole, or upon one element of the subject. Thus, the whole line scan may be considered to be made up of a whole series of these elementary circular areas, each of which is exactly as wide as it is high. If the picture is square, the total number of picture elements will be equal to the square of the number of lines, thus if we use a 45 line scanner, the picture will have (45 x 45) or 2,025 elements. The definition of the square picture, therefore, will increase as the square of the number of lines.

The ratio of the width of a picture to its height is called its aspect ratio. In most mechanical systems the aspect ratio is about 1 to 1. It has been found from actual experiment that the width should be greater than the height for the best entertainment value, or rather for most pleasing appearance. In modern television receivers, therefore, it is the practice to standardize an aspect ratio of 4 to 3. If the number of lines is equal to 525 as has been declared the standard in United States, by the Federal Communications Commission, then the total number of picture elements will be $4/3 \times 525^2$ or 334,167. To obtain the total frequency coverage required by the television amplifier, we divide by 2 to obtain the number of cycles, because the greatest number of contrasting elements would occur if each alternate element were black and white respectively. Then we multiply by the number of pictures per second which has been standardized to 30 so that the total frequency coverage required will be 30/2 x 334,167 or is equal to 5,012,505 cycles per second down to about 15 cycles per second.

The aperture type scanning disc is usually constructed of a thin sheet of steel or aluminum and rotated by a small synchronous motor. In the simple form of the disc, holes are arranged around its outer edge in the form of a spiral. The holes are arranged evenly around the diameter, i.e., if there are twenty-four holes, each is 15° from the other around the disc. If there are 45 holes, each is 8^{o} apart. The picture is assumed to be approximately square so that the height of the picture would be equal to the linear distance between the holes. The holes should have a diameter equal to the height divided by the number of holes. Thus, the dimension will be directly proportional to the number of holes and to the radius of the disc, and the size of the holes will vary accordingly.

A 22/1000 diameter hole is considered standard size for a 17 inch diameter scanning disc, though the holes at the transmitter may be a little smaller than this to increase the definition and the holes of the receiver disc made larger to increase the amount of light on the image screen. These processes are called underlap and overlap respectively. The size of the scanning holes for larger or smaller discs may be developed proportionally. Thus, a 34 inch disc would use 34/17 x 22/1000 or 44/1000 inch holes. The radial distance between the holes is zero so that the height of the picture is the number of holes times the diameter of each. Thus, the height of a 45 line picture on a 17 inch disc would be about 45 x 22/1000, or .99 inches.

Fig. 3.

The width of the picture will be seen to vary from the top to the bottom of the picture because the holes are located on the radii and naturally these must be closer together near the center of the circle than near the rim. This is called the Keystone shape. Also, as the scanning disc rotates, the holes will sweep out arcs rather than straight lines. Both these effects are of negligible importance because the size of the picture is kept small compared to the size of the disc. The amount of light passing through the aperture decreases seriously with the number of scanning lines employed, so that the aperture disc is satisfactory only up to 180 lines. When a large number of lines (anything above 100 lines is a large number of lines for a scanning disc) are employed, the disc must become quite large to accomodate such a large number of holes if the latter are of reasonable diameter. It is obvious that the size of the hole cannot be decreased indefinitely for light considerations, so that the size of the disc must increase. There is a limit, of course, to the size of the disc which can be employed without making the apparatus so unwieldy that it becomes impractical.

It is obvious that the circular hole type of aperture is the cheapest to manufacture, but it is considered by many television engineers to be inferior as far as definition is concerned as well as evenness of illumination. The definition of the transmitted picture is strictly proportional to the horizontal width of the scanning aperture. That is, the smaller the horizontal width, the greater the definition of the picture. While it has been stated that an aperture can resolve a point only the same size as itself, there is reason to believe that this is not strictly true. Apparently, slightly greater definition can be achieved by the use of proper electrical circuits. Nevertheless, the resolution is still proportional to the size of the aperture. If the aperture is circular, then there will be more light passing through its center than its edges. This unequal illumination of the line scan tends to produce dark lines which run through the picture. To overcome both these difficulties, some manufacturers used a rectangle aperture which may be either square or oblong. If the width is less than the length, then the horizontal definition will be much greater than the vertical definition of the picture.

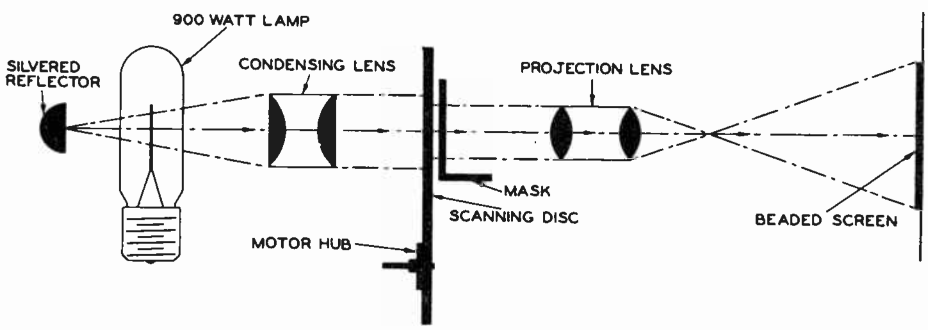


Fig. 4.

The advantages other than an economy in the manufacture of a disc with a smaller number of apertures is questionable. When an aperture disc is used, light from the source must obviously cover the whole picture raster in spite of the fact that only a small fraction of it is actually being used at one time. If the source is small, then a lens must be used together with a diffusing screen so that light may cover the masking aperture. Obviously, such an arrangement is extremely inefficient from the source standpoint. A modified version of the aperture disc uses more than one spiral and a moving aperture, which is geared to the motor. Thus, the holes of the disc may be made larger and more light can pass through. The gearing arrangement necessary to move the aperture usually is sufficient to condemn it on practical grounds. Economically, the device is more expensive. Mechanically, it is more complex and backlash troubles alone are very serious. Another modification is the aperture drum which has little, if anything, in the way of an advantage over the disc. In fact, the problem of lining up and centering is much more complex. The distortion of the picture raster does not assume the usual Keystone shape, but a characteristic distortion does occur. The drum, like the disc, must be accurately centered, and this is usually done dynamically. This disc is mounted on its shaft and the motor is started. The flanges which maintain the disc in its proper position are slightly loosened and the disc is lightly tapped on the rim until balance is achieved. The motor is then stopped, and the flanges are tightened up. In the case of the drum there are two bearings, and thus, two flanges. The drum has one advantage, and that is it allows a much smaller scanner than would be required if a disc were used. The allowable tolerance in the scanning hole spacing, diameter, etc., is quite small, and therefore an original disc is quite expensive to manufacture. Once the jig has been made, however, the cost becomes quite reasonable. This accuracy is characteristic of any mechanical scanning system. The mounting of the various mirrors and mirror drums, etc., must be done with a minimum amount of errors.

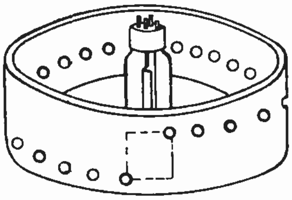


Fig. 5.

Before we depart from aperture disc scanners, let us discuss methods of scanning briefly, It was in the practice in the past of English manufacturers to have the picture line scanned vertically and the frame scanned horizontally, while the United States and Germany, the reverse was true. The present day practice is to line scan horizontally and the frame is scanned vertically. The first of these is called the direct scanning method, and the second the indirect or flying spot method.
In the first case, an image is formed of the subject by a lens in the plane of the aperture disc and a photo cell is placed on the side opposite. In the second case a strong source of light is placed behind the disc and an objective lens in front of it so that the subject is scanned by moving a spot of light. Photo cells in large reflectors are placed so that light is reflected from the subject to them. If all of the placements of the elements of both systems were the same and the elements the same size, the effeciency would be the same. However, this is not the case usually and the indirect method is to be preferred by far. It has the disadvantage of being applicable only to small scenes or views, such as the head and shoulders of a person, while the direct method can scan whole scenes. For the higher number of lines, however, the flying spot method is the only one which can be used, because the amount of light passing through the photo cell in the case of the direct method is so small that only a few electrons are caused to flow in the circuit.

In working out the layout of a television system we can find the required parameters and distances by the application of relatively simple formulae. To illustrate this, let us take the following example. Suppose that we have a 45 line, 34 inch scanning disc at our television transmitter. We have to scan an area of 20 x 20 inches and the throw distance is to be 36 inches. It is required to find the distance between the objective lens and the scanning disc, and also the focal length of the lens required.

Form of Aperture	Area of Aperture	Number of Apertures	Size of Scanning Device	Furnished Detail
 S, S	S^2	n	D	P
 S/2, S/2	$\frac{S^2}{4}$	2n	2D	4P
 S, S/4	$\frac{S^2}{4}$	n	D	4P

Table 1.

We must first find the height of the picture at the scanning disc. As the picture hole diameter is 22/1000 for a 17 inch disc, the height of the picture will be 2 x 22/1000 x 45 or 1.98 inches. Magnification of the system is equal to the length of the image divided by the length of the object. Taking the latter to be 2 inches, the magnification will be 20/2 or 10. We also know, however, that the magnification is equal to the image distance divided by the object distance so that length of the lens can be found from the formula:

$$\frac{1}{U} + \frac{1}{V} = \frac{1}{F}$$

$$\frac{1}{3.6} + \frac{1}{36} = \frac{1}{F}$$

$$F = 3\ 3/11 \text{ inches}$$

Suppose that we had available a glow lamp which produced an area of light 1/16 of an inch in diameter. If a lens disc equipped with lenses having a focal length of 3 inches were used and it was placed 4 inches from the glow crater, what would be the throw distance of the system? What would be the width of the line appearing on the screen?

$$\frac{1}{U} + \frac{1}{V} = \frac{1}{F}$$

Source of light equals 1/16 inch diameter.
Focal length of lens equals 3 inches.
Distance from source to light equals 4 inches

$$\frac{1}{U} + \frac{1}{V} = \frac{1}{F}$$

F = 3 inches
U = 4 inches
V = distance from lens to screen

Substituting: $\frac{1}{4} + \frac{1}{V} = \frac{1}{3}$; $\frac{1}{V} = \frac{1}{3} - \frac{1}{4} = \frac{1}{12}$

V = 12 inches

Magnification: $M = \frac{V}{U} = \frac{12}{4} = 3$; $\frac{1}{16} \times 3 = \frac{3}{16}$ inches width of line on screen.

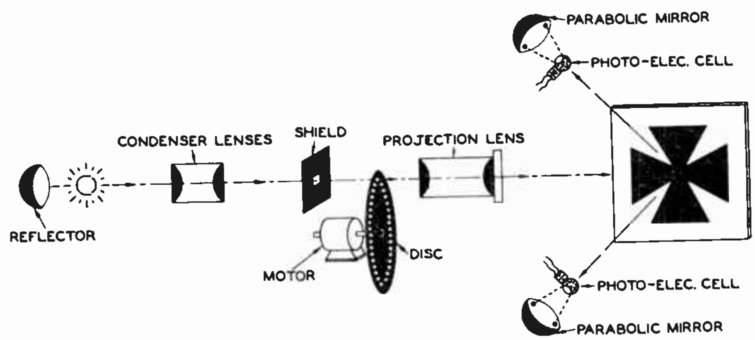


Fig. 6.

Many television engineers had been pretty well convinced that the aperture disc had outlived its usefulness when they were confronted at television exhibitions in Berlin in 1936 and 1937 with a 375 line film scanner. Even the construction of such a disc had been considered out of the question, but there it was doing its job even better than many of the modern picture pick-up devices. Dr. Moller, the famous German engineer who had done so much in the field of mechanical scanning, has stated that the aperture disc is superior to any other system if it is remembered that it can pick up practically any type of scene with little differentation. The pictures given by such a disc are said to be almost perfect in definition and contrast. One of the main difficulties, other than light inefficiency due to the small holes, has been the power required to drive the large disc and also the difficulty with dust getting into the apertures. As the disc is only to be used at the transmitter, then methods can be used which otherwise would be unsuitable. One of these methods which has proven quite satisfactory is to enclose the disc in a partially evacuated chamber. This immediately does away with both of the difficulties mentioned. From these remarks you may gather that the King aperture disc has been by no means completely deposed. In the realm of transmission, at least, we can look forward to aperture disc scanning for some time to come.

Some years ago a rather novel form of television scanner was developed by the late C. Francis Jenkins. See Fig. 7. Prisms were arranged in a circle near the edge of a scanning disc and each of them was ground so that the light would be refracted to a different degree. Thus, as the disc revolved, light from a point source could be made to scan a screen in the usual manner. The device was very soon supplanted by the more economical lens disc. The cost of actually grinding these prisms, mounting them, etc., was extremely high.

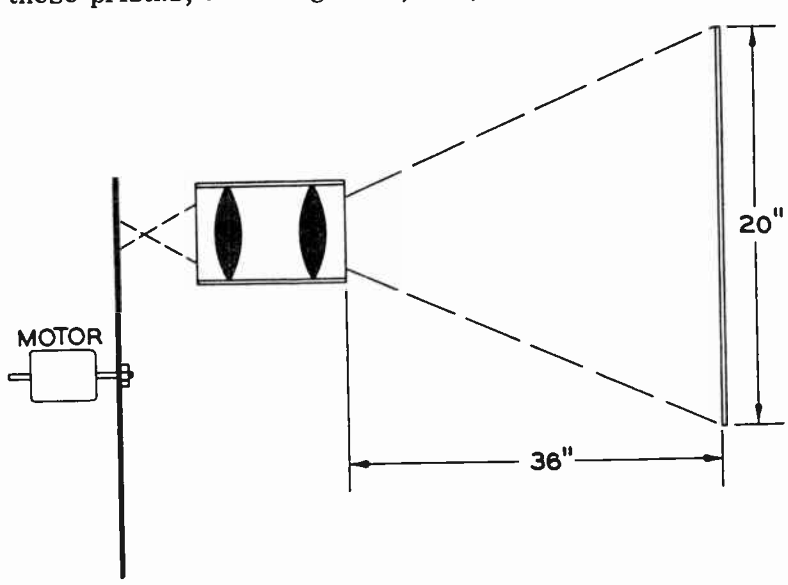
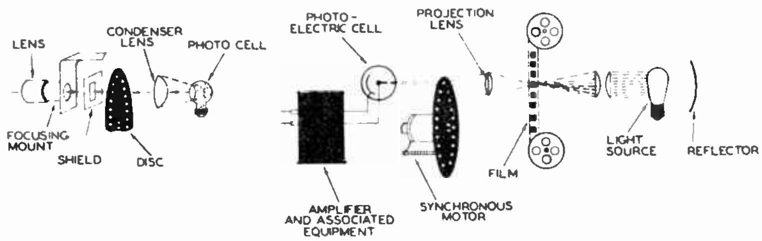


Fig. 7.

The apertures of a scanning disc may be replaced by simple double convex lenses which are fitted into sockets around the periphery of the disc. The size of the lens makes the disc diameter required much larger, but this type of scanner has the advantage of not requiring an objective lens, nor a large source of light, and thereby its practicability is quite great. Amazing is the fact that its efficiency is no greater than that of the aperture disc. This, of course, is due to the fact that either a point source or an aperture is required so that the lens may form an image of this source or aperture on the screen. The only change as far as the system is concerned, other than the advantages mentioned above, is that the lens is moving and the aperture is stationary; in the former case the aperture was moving and the lens was stationary. The lenses must be accurately fitted in their sockets, and this is more difficult a problem than would at first be supposed, as the lens is quite fragile. The usual practice is to drill a hole slightly smaller than the lens right through so that a rim will be formed. The lens is then inserted, and a ring may be placed over the lens. Small screws may then be used to hold the ring in place, or the lenses may simply be peened in place. The lenses in the lens disc are not displaced by the diameter of the lens along the radius, but only by an amount equal to the spot diameter. Thus, the spots formed on the translucent screen will just touch one another sideways as there must be some metal between them to act as a support. There is a very definite limit therefore to the size of the lenses which can be used in a disc of a given diameter. They are usually as large as is practicable so that a maximum amount of light will be gathered from the point source.



Film Scanning

Fig 8.

A small type of lens disc receiver was manufactured in quite a large quantity in 1932 by the Western Television Corporation. This system used a 45-line triple interlaced lens disc of 8 inches diameter. A small (about 3 inches in diameter) synchronous motor was used to turn at 900 R.P.M., or to form 15 pictures per second. A small argon arc discharge tube was used which furnished an almost black and white picture, approximately 4 x 5 inches, on the translucent screen. A superheterodyne receiver was incorporated, and it was one of the first successful really commercial receivers. Many of them were sold in the vicinity of Chicago where they picked up quite good pictures from the transmitter of W9XAO. This model was called the "Visionette" receiver and a little later a slightly different model having a screen size of about 6 x 6 1/2 inches was put on the market which used the same type of scanning disc as the visionette but larger (10 1/2 inches). The lenses in the larger receiver were 1/2 inch in diameter, while those in the visionette model were 4/5 inches in diameter. Lenses can be arranged in a drum much in the same manner as apertures, but the same difficulties apply to lens drums as those which apply to the aperture drums. Thus, lens drums are little used except in combination with mirror drums. One of the first to use this idea was John Baird and he called it the "optical lever principle". The only present day company to use this principle is the Scophony Company which utilizes it in their lens drum film scanner.

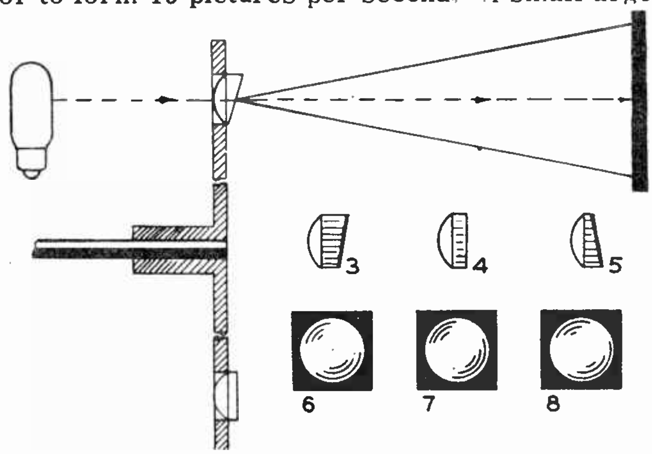
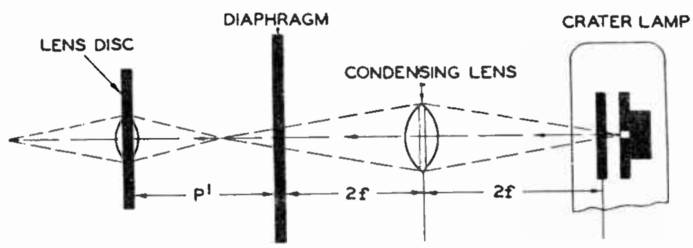


Fig. 9.

Vibrating Mirrors

Many inventors have suggested the use of vibrating mirrors to effect the line and frame scanning. Up to the present time such devices have proven to be failures. The main reason for this is that oscillating masses tend to vibrate sinusoidally which is, of course, not satisfactory for television purposes. Furthermore, at the high vibration rates required for the line scanning of the now standard picture, extreme difficulties were experienced in obtaining even a workable design. A problem presents itself in the design of driving means for the oscillating mirror. At high frequencies this is a real difficulty, especially if the deflection is to be anything other than sinusoidal. Mirrors that would be useful for this purpose must be very small in size, consequently, the light efficiency must be small unless the aperature of the system is placed near the scanning mirror. If this is done, the compactness of the system is largely destroyed. For this reason, no commercial receivers have been designed which use this principle and at the present time the idea seems to have been completely discarded.



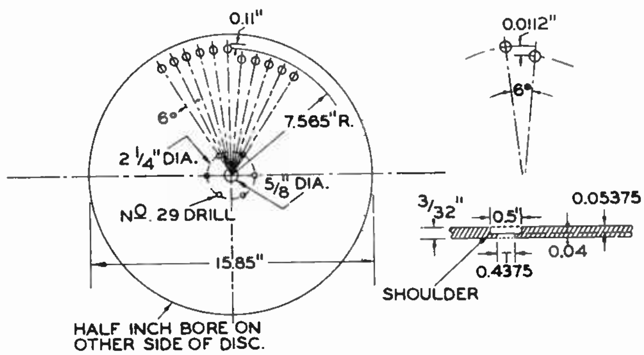


Fig. 10.

The Mirror Drum

There are several arrangements of mirror drums which are used in television scanning systems. In one of these a single mirror is used in which the mirrors are slightly tilted to vary in degrees around the periphery. This tilt is called the cant of the mirror and by reason of the cant and the revolution of the drum both horizontal and vertical scans occur simultaneously. Alternatively, two mirror drums may be used, one which turns at a slow speed for the frame scan, while the other turns at a high speed for the line scan. Neither of these drums need be canted. It is evident that when two scanners are used in combination, they must be either geared or belted so that they will run synchronously. It has been the experience of television engineers that such methods are rather difficult to achieve practically. It is extremely difficult to use gear systems for television purposes. It is even more difficult to use belted systems due to the slippage of the belt. Another method is to use two synchronous motors, one for each of the drums, but, of course, this has obvious disadvantages. The efficiency of the mirror drum is greater than the aperture or lens disc arrangements, as long as the line number is kept below about 50 lines. Above this line number the other systems are more efficient. The mirror drum, however, has definite advantages at the television receiver in spite of the fact that it has been totally abandoned at the transmitting end. This advantage will be obvious upon inspection of Figure 12. Compactness of the tele-

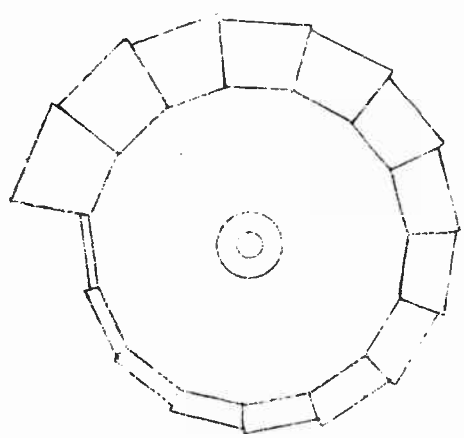


Fig. 11.

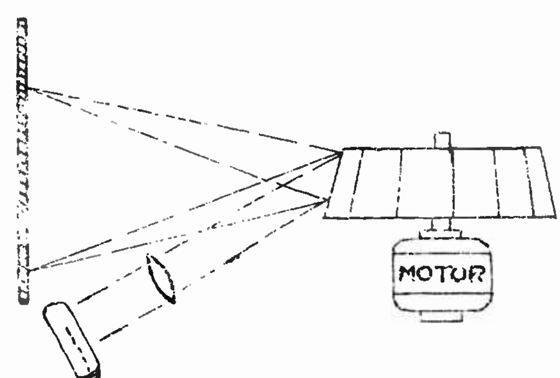


Fig. 12.

vision receiver is essential and this is the chief advantage that the mirror drum has to offer. By suitable arrangement of lens system, so that the latter is between the drum and the light valve, definite economies in space are effected. Surface mirrors are, of course, to be preferred; but in actual practice, they are not widely used because the surfaces are extremely difficult to maintain untarnished. For this reason, silver back glass mirrors or polished metal are usually used.

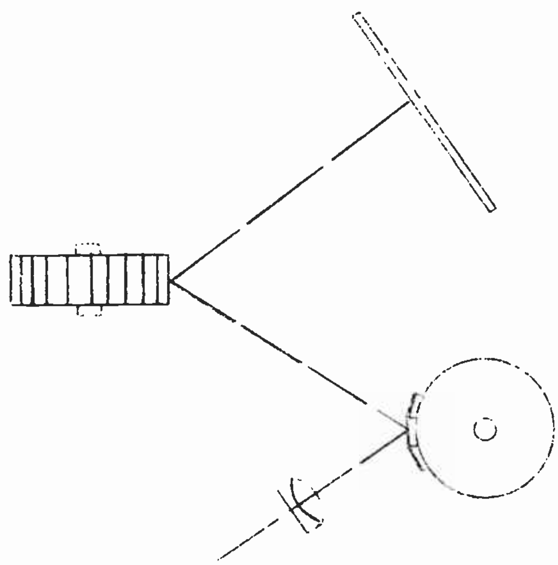


Fig. 13.

The cant of the mirrors used in a single drum system must be very carefully adjusted so that the lines in the picture are equally spaced. It is difficult, indeed, to do this directly on a jig, so the final adjustment is usually left until the drum is mounted in place and the lines can be seen on the screen. The mirror is slowly turned by hand and the portion where each light trace strikes the screen is marked. Any mirrors which are out of place can thus be easily detected. The mirrors are usually mounted on tabs which can be bent slightly, or mounted with screws so that their tilt or cant can be easily changed.

Another simple method of using mirrors in a television scanning system is to place them in a disc instead of lenses. The light in this case will be reflected from the disc rather than passing through it, as in the case of the lens disc. Some difficulties are usually encountered in the latter by reason of the chromatic and spherical aberration, to say nothing of the other distortions. In the case of the mirror disc, however, chromatic aberration is automatically eliminated, which is a decided advantage. The method of mounting these concave mirrors into a disc is quite an interesting one. The holes in the disc are usually drilled smaller than the mirrors themselves. The latter are then cooled by application of liquid air or prolonged exposure to dry ice (solid carbon dioxide). They then contract to a size smaller than the diameter of the holes in the disc, and may be inserted. When they regain the normal temperature they become so tightly wedged that they may be said to have become an almost integral part of the disc. Either plane or concave mirrors may be used, depending upon the associated optical system. It is usually more efficient to use concave mirrors because convergence and reflection is then obtained with but a single optical device.

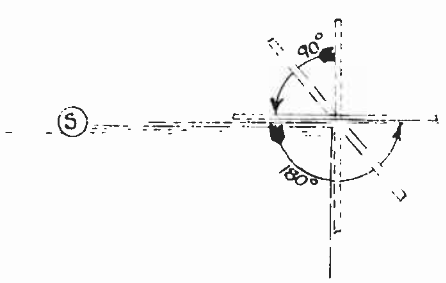


Fig. 14.

When we consider the scanning of a screen by a mirror, we must remember that the spot moves across the screen twice as fast as the mirror turns. This is simply due to the fact that the angle of incidence of the light must be equal to the angle of reflection. For instance, if the light falls upon the mirror normally, then it will be reflected back exactly the opposite direction along the normal plane to the surface. If the mirror surface is in practically the same plane as the incident light, then it will be practically unreflected. Thus, if the mirror is rotated through an angle of 90°, then the reflected light will be rotated through an angle of 180°.

This fact is of much value in mechanical scanning systems. When these systems are designed, of course, the mirrors should be arranged so that the light falls upon them at nearly normal incidence as possible. This will keep the losses within reasonable limits. In some set-ups, however, considerable deviation from this rule occurs. One of the instances where the rule cannot be used is in the receiver of the Mihaly-Traub type. Here the arrangement of the parts must allow a rather compact design. For this reason, a certain amount of light loss must be tolerated, and an actual angle of 37^{o} is used. As the incidence of the light to the scanning mirror varies with its movement, the amount of light reflected must also vary. This tends to result in an unequal illumination of the screen, the edges being dimmer than the center portion. To overcome this fault, the stationary mirrors of the line scan arrangement in the Mihaly-Traub system are but half the width of the mirrors used on the rotating drum. This insures adequate illumination of the stationary mirrors at all times.

The curvature of the lines of the various scanning systems varies considerable. We have seen that the lines are really arcs of circles in the case of the aperture scanning discs. In the case of the simple mirror drum, which uses canted mirrors to produce the frame deflection, the curvature will obviously change with the position of the line in the picture. The center line of the frame usually has no tilt whatever, while the mirrors corresponding to the top and bottom lines are tilted equally but in opposite directions. By this means the curvature of the lines is kept small.

We have seen that the efficiency of a single mirror drum scanner is inferior to the aperture disc when a reasonable number of lines are used. In an effort to get more and more light on the screen, the area of each scanning mirror was increased, but it was found that to obtain a reasonable illumination of the screen enormously large scanning drums had to be used. These were obviously impractical for television receiver use. The first great advancement was due to Mihaly who used a single double-faced mirror rotating inside a ring of smaller mirrors. Thus, the scanning angle was multiplied without increasing the size of the mirrors. As the amount of light falling on the screen is proportional to the solid angle formed by the scanning movements, then the illumination of the screen must increase with a larger angle. Traub later modified this system by using only a portion of the stationary ring of mirrors, but increasing the number of mirrors that rotated. The mirrors in the stationary sector are canted to provide the frame sweep, just as in the Mihaly system, but the number of mirrors used can be greatly reduced. For instance, if a 100 line system is desired in the original Mihaly system, 100 mirrors would be required. If, in the Traub modification 5 involving mirrors were used at the center, then only 20 (100/5) mirrors need be used in the ring. This, of course, is a very great advantage; not only is the loss reduced, but the device is more economical to construct and easier to maintain.

If two mirror drums are used, one which produces the frame scan and the other the line scan, a certain independence of speed of rotation of the drums is gained. For instance, if but

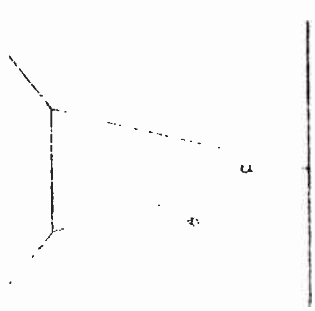


Fig. 15.

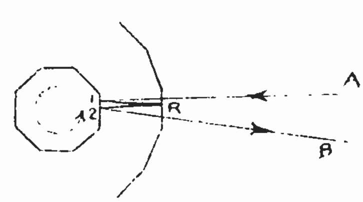


Fig. 16.

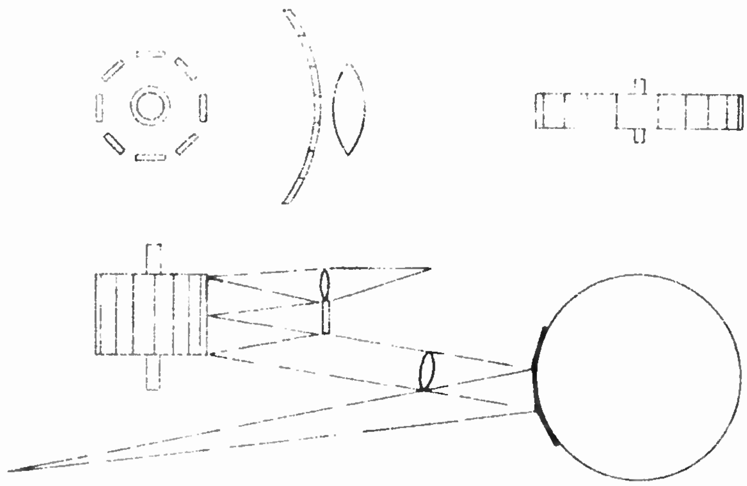


Fig. 17.

a single drum is used both for frame and line scanning, then there must be as many mirrors on the drum as there are to be lines on the picture. Furthermore, the period of rotation of the drums must be equal to the frame period of the picture. Thus, if a picture is to reproduce 100 lines at 30 frames per second, then the drum must have 100 mirrors and rotate at a speed of 30 revolutions per second, or 1,800 R.P.M. If, however, two drums are used (this is called the cross drum system) this is no longer true. The frame scan drum may contain 5 mirrors and if there are to be 30 frames per second, then it need rotate but 30/5 or 6 revolutions per second. The frame scan drum is usually placed between the line scan drum and the screen, and as the former has such a few mirrors, they can be quite large so that a large amount of light can be transmitted to the screen. Now, as the line scanner need no longer perform the frame scan as well, it can rotate several times during one frame. Thus, the number of mirrors required for a given number of lines will be decreased proportionally. For instance, in the first case we needed 100 mirrors for 100 lines. In the case of the cross drum arrangement we can use 20 mirrors and rotate the drum 5 times as fast. Now the fact is, the faster we rotate the line scan drum the greater the amount of light that will pass to the screen, so that in modern mechanical scanning systems this speed may easily be 13,000 R.P.M. With the increase in light given by the high speed scanning, it has been found possible to reduce the size of the mirrors materially. Some of these mirror drums are but 1 to 2 cm. in diameter, and thus, they can be made from a solid piece of glass which is not only strong enough to withstand the large centrifugal forces, but also may be arranged so accurately that they never require further adjustment. The stationary mirrors can also be made from one piece of highly polished metal so that they too need have no further adjustment after they have once been set up. In the Mihaly-Traub television receiver made by the International Television Company, a 9 sided rotating mirror is used together with 5 stationary mirrors. This rotating drum turns 9 times per frame so that 405 lines are produced. The picture size is approximately 20 x 16 inches, and the apparent illumination of the screen is about 5 lux.

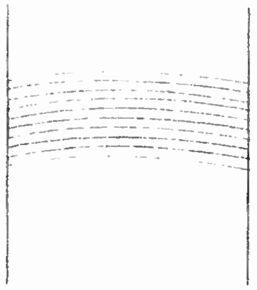


Fig. 18.

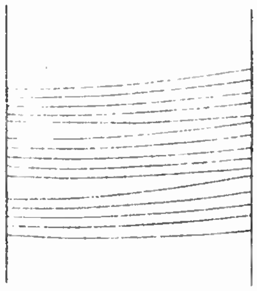
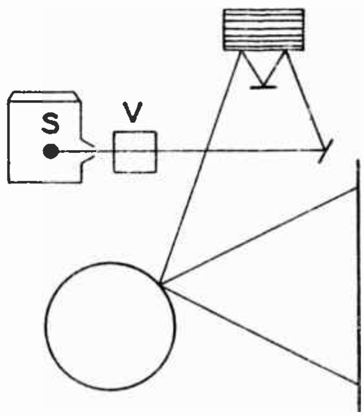


Fig. 19.

If the light through the scanning system of the receiver described above is parallel, the lines traced out on the screen will be uniformly curved upwards as shown in Fig. 18. If, however the light is convergent through the system, a distortion termed "trapezoid error" will be observed. See Fig. 19. This distortion gets its name from the fact that each five lines of the raster forms a type of trapezium shaped figure. Both these distortions can be eliminated by using an aperture after the line scanner so that only a straight portion of the scan is allowed to pass through on to the frame scanner and thence to the screen. We should mention that if the light is divergent the effects are similar to that shown when it is convergent through the scanner except that the trapezium is reversed.



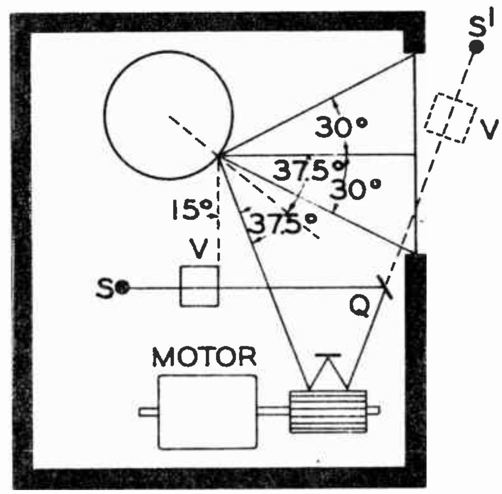


Fig. 20. Mihaly-Traub Receivers. At left, plan of big screen receiver. At right, plan of home receiver.

Even if the curvature of the lines of the picture is eliminated by either optical means or aperture selection, the image field will still be curved. This is due to the fact that the focal distance from the frame or slow drum scanner is constant irrespective of its position, and therefore the focal point will travel across the arc of a circle rather than in a straight line. If the slow drum is near the screen and the scanning angle is correspondingly large, then the curvature of the field may become so great that the definition at the sides of the picture may become unsatisfactory. Furthermore, the greater the scanning angle, the less will be the depth of focus of the scanning system so that the curvature of field will become even more serious. It is therefore necessary to keep the slow drum just as far from the screen as feasible. Of course this will correspondingly decrease the efficiency of the system, and this is one of the many cases where definition and light efficiency require contradictory conditions. In the small home receiver, the slow drum is placed at the top of the cabinet while in the large screen receiver, where the drum is of quite large dimensions, it is usually placed lower than the rest of the system.

A novel arrangement originated in Germany some years ago is the mirror screw. See Fig. 21. This is quite a unique arrangement using flat plates with their edges silvered, and turned about a vertical axis so that they take on the appearance which is characteristic of their name. The original flat element mirror screw had the immediate disadvantage of a large viewing distance. This, of course, is not compatible with the requirements of a television receiver. In an effort to cut down this viewing distance the inventor modified his original design so that the element mirrors were concave rather than plane. This did materially decrease the viewing distance required, but it has been found that ironically enough the mirror screw must be viewed at such distances that the highest definition of the picture it forms cannot be resolved by the eye at that distance. In other words, it is not possible to use the definition achieved by such an arrangment. This factor together with that disadvantage common to all simple mirror arrangements of becoming inferior to the aperture disc at about 50 lines has condemned this device to the television apparatus museum. Notice from the diagrams that the mirror screw requires a long light source. In fact, a light source as long as itself, unless condensing lenses are used. Due to the manifest advantages of a point source of light,

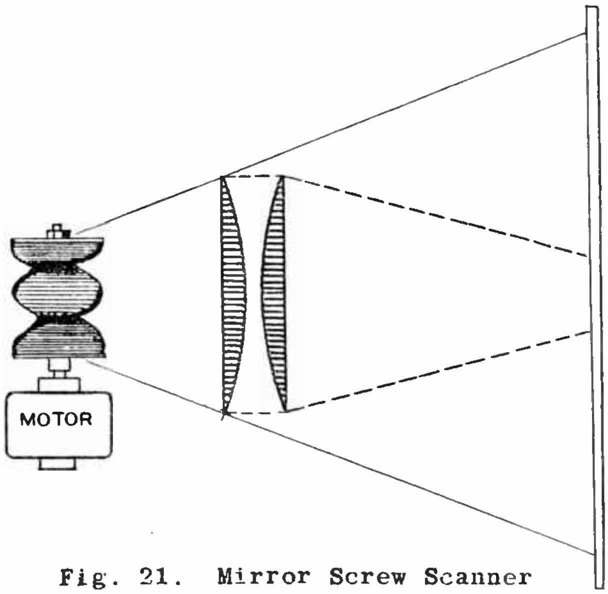


Fig. 21. Mirror Screw Scanner

the condensing lens usually is used, but naturally the losses of reflection and absorption occur.

The efficiency of the various scanning systems is listed in Table 2. It should be kept in mind that the values given depend upon identical apparatus being used. In practice, this assumption will usually not hold water, because if such proportions were used, the device would become impractical for either reasons of expense or light efficiency. For instance, in the table, the aperture disc is listed as having the same efficiency as the lens disc, as we have pointed out before. This would entail the use of a large source of light for the aperture disc having the same intrinsic brilliancy as a point source of light would in the case where a lens disc was used. This obviously never occurs in practice. The intrinsic brilliancy of the point source is many times greater than that of the large sources of light. This may be realized at once when it is remembered that the flat plate glow lamp is used for the aperture disc while the crater type gas discharge tube is used for the lens disc arrangement. Also even if the crater lamp is used for the aperture disc, only a small portion of the surface is of value at any one time, whereas in the case of the lens disc all of the light is used all of the time. You

Table 2. Characteristics of Mechanical Optical Scanning Systems.

Scanning System	Light Output in Lumens = Lux for 1 m^2 Picture							
	120 lines	240 lines	B	D	t	p	q	k
Aperture Disc	0.7	0.045	80,000	100	0.1	1		2
Mirror Drum	0.004	0.000065	80,000	100	0.1	1		
Double Mirror Drum	1.6	0.018	80,000	50	0.1	4		
Mihaly-Traub	0.08	0.0012	80,000	10	0.1	1	30	
Mirror Screw Real Image	0.002	0.000063	80,000	r=5	0.1			2
Lens Disc	0.7	0.045	80,000	100	0.1			2
Multiplying Lens Drum	2.8	0.18	80,000	50	0.1	4		2

B = Brightness, always in candles/cm^2
D = Effective diameter of scanning member
K = Picture ratio. K = L/W.
N = Number of elements. $N = K_n^2$
k = Aperture ratio or f/number of objective

p = Number of revolutions of scanning member to effect one complete picture scan. This is the so-called speed factor.
q = Number of rings, or complementary mirrors.
t = Transmission loss factor.

will see also that when a crater lamp is used with an aperture disc a magnifying lens and a diffusing screen must be used as well, and naturally losses are encountered.

It will be self-evident that the number of mirrors and lenses in any optical system must be kept to a minimum so that the light losses will not be too exhorbitant. The mechanical scanning systems are no exception to the rule, and it is a fact that many otherwise excellent scanning systems are useless, because of all the amount of light from the source at the receiver, only a fraction of 1 percent can possibly emerge and be used at the screen. It is obvious that really well corrected lenses cannot be used for most mechanical television systems. Highly corrected objective systems have a relatively enormous loss and thus it is usually recommended that doublets corrected for chromatic and spherical aberration alone should be used on the most important ground of light efficiency. When reflectors have to be used at large angles of incidence, it is necessary to use the total reflection occuring at the inside face of a prism. While the latter is by far a more expensive device, the expense is more than counter-balanced by the efficiency gain. The greatest single loss in the mechanical systems occurs at the light valve. Light valves usually have an efficiency of but 10%.

Motors and Synchronizing

The synchronizing of mechanical systems is a great deal more complex than that which we have studied in regard to cathode-ray systems. The main reason for this complexity is due to the fact that the mechanical scanner has inertia, and therefore considerable power must be used to pull and then lock into step the scanning elements. It is interesting to note here that when the Scophony Company first used their commercial television outfits to receive a picture transmitted by an iconoscope, there was considerable difficulty in synchronizing the two. The iconoscope sweep circuits would slow up, then run fast and vary intermittently. With the cathode-ray tube, of course where the scanning means have no inertia, it follows the synchronizing pulses of the transmitter with greater accuracy. Such irregularities however, were extremely difficult to allow or compensate for in the mechanical system. It was not until the spontaneous changes in the iconoscope were eliminated that good pictures could be obtained from the mechanical receiver.

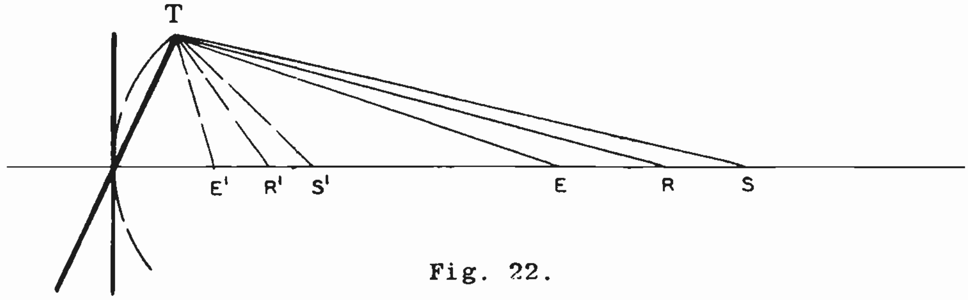
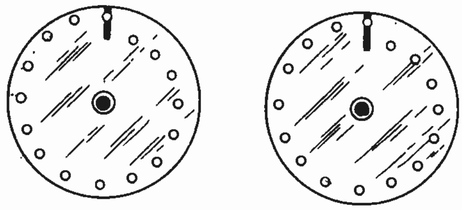
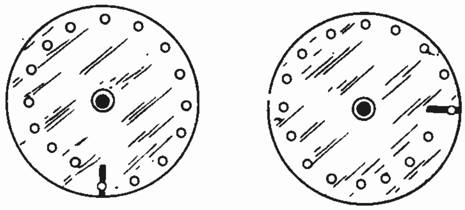


Fig. 22.

The synchronization of two aperture discs is one of the oldest problems in the television art. In the 1890's it was suggested that synchronous motors running from the same power line should be used. Thus, the discs would run isochronously, and to make them run synchronously it would only be necessary to turn the motor with respect to its mounting so that the discs would be brought into frame. Such an arrangement is an extremely simple one. It was used in the old A.T.L. television outfit, which utilized small hundredth horse power synchronous motors running on 100 volts, 60 cycles A.C. When broadcasting of the television signals is to occur over quite a great distance, then it may be difficult to obtain the same power line as that actuating the transmitter. The frequency may be just a trifle below or above that at the transmitting end, and difficulties will therefore occur. For these and other reasons, the early television receivers used to use a variable speed electric motor. By adjusting a resistor in the motor field, its speed could be varied so that the picture would be running isochronously with the transmitter and framing could then be easily accomplished. Such an



Discs in Syncnronism (perfect step)



Discs in Isochronism (same speed) but not synchronized (picture out of frame)

Fig. 23. The illustration above shows that while you may have transmitter and receiver scanning discs revolving in step, the picture may still be out of frame.

arrangement is not desirable because the picture is usually either slipping a frame or two so that the device requires almost constant attention. Synchronizing pulses were then transmitted over the air with the picture signals and these pulses were separated from the latter at the receiver, amplified and then applied to a synchronizing device.

A synchronizing device that was used in the days of mechanical television consisted of an electro magnet energized by the receiving circuit and placed beside a slotted copper disc and mounted on the shaft of the scanning motor. The latter was arranged to run slightly fast, and when the synchronizing pulses passed through the electromagnet, it exerted a drag on the copper disc due to the eddy currents set up therein. When the motor was slowed down to the proper speed and was in synchronism, then the slot would be in front of the electromagnet pole when the impulse arrived, and so, of course, the pulse had no action on the motor whatever. In this way the motor would attempt to speed up after each pulse, but would be pulled back into step at the end of each line. If the wandering was kept small, then the device could be kept in fairly good synchronism.

Another device consisted of a small tooth wheel arrangement which worked something after the style of induction motor. While this accomplished syncrhonism, it had the disadvantage of requiring extra amplifying stages and a considerable amount of power. Furthermore, it added to the expense and bulk of the receiving apparatus. It is, however, one of the most suitable methods of synchronizing a mechanical receiver.

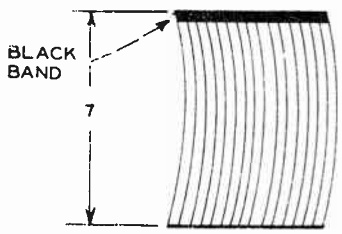


Fig. 24.

When synchronous motors are used to drive the transmitter and the receiver of the television system, they will most certainly be in step, but it is unlikely that the receiver will be properly framed. That is, the scanning velocity will be the same, but any single hole in the aperture disc at the transmitter will not correspond in position to that same hole in the aperture disc at the receiver. For this reason, the scanning motor at the receiver is mounted so that it can be turned within the supporting frame. When the picture is received, the motor can quickly be turned so that the proper framing is accomplished. When interlaced scanning is used, it is essential that the receiver be operating on the right spirial and therefore the same adjustment must be made in this case as that outlined above. When synchronizing pulses are transmitted with a picture signal, then it is usually the practice to include frame signals as well as line scan signals, so that any further adjustment of the receiver is unnecessary.

Before leaving the subject let us look at the considerations required to minimize a type of picture distortion. The scanning means must be carefully designed to reduce the vibration to a minimum. Unpleasant distortion of the picture occurs if any part of the scanning disc or drum mirror system is subject to appreciable vibration. For this reason the disc and its motor are very often suspended on rubbor supports. Earlier attempts to reduce this vibration sometimes consisted of rubber connecting links between the disc and the motor. This was found to cause oscillations of the disc about its driving shaft so it was later abandoned. The use of springs in this connection would fail for the same reason, thus, the development of the so-called mechanical filter between the driving motor and its support described above.

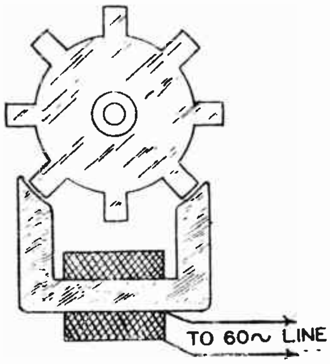


Fig. 25.
Tooth wheel for synchronizing.

Multi-Channel Television Systems

You will be familiar with the fact that enormously high frequencies are generated by the television transmitter; also, quite low ones are formed. It is obvious that to obtain a picture which corresponds exactly to the subject, the amplifier must be capable of passing equally the whole frequency range between these extremes. This is a very serious problem in the design of amplifiers, and in an effort to obviate this difficulty, the multi-channel system was devised. In this system, elementary areas of the subject may be separately scanned by different scanning systems using separate photo cells or a single scanning means may be used with several photo cells. Separate amplifiers are attached to each of the photocells and separate lines from each of the amplifiers go to the glow lamps or light sources or valves at the receiver. A separate light source or valve must be used for each channel. For instance, if ten channels are used, each having about 20 lines, then each of the amplifiers need only pass one-tenth of the frequency band that would be required by a television outfit using a single channel. Obviously, their design is a great deal simpler, yet a raster of 200 lines is secured.

Such a system was that embodied by U.S. Sanabria's Television outfit built in 1933. It was a 10 channel, 150-line affair having a lens equipped with 15 lenses and using 10 small photo cells. The amplifiers used 65 tubes each making a total of 650 in all. At the receiver another 15 lens disc was used with a special glow lamp about 30 inches long having 10 separate arc discharge streams. The lenses were 7 inches in diameter and the whole disc about 44 inches in diameter. Extremely brilliant pictures were exhibited in many large department stores and theaters throughout the country. The device was extremely successful for show purposes as you can well imagine. For home use, however, such a device would obviously be totally unsuitable, as the equipment is said to occupy about a box car. The device gave pictures from 6 to 10 feet square. It used the direct scanning system, which is more suitable when multi-channel arrangements are used.

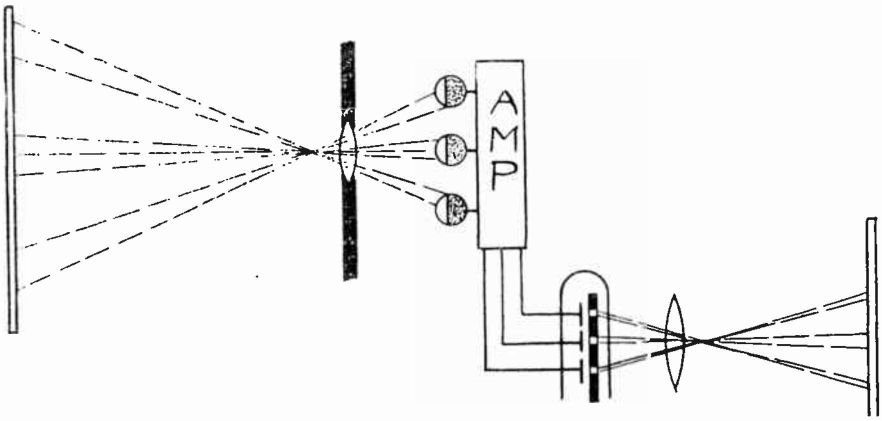


Fig. 26. Principle of zone or multi-channel television.

CHAPTER III

MECHANICAL SCANNING SYSTEMS II

In the previous section on Mechanical Scanning Systems, we dealt only very generally with the various factors. We must know much more about the considerations involved in the design of such systems before we are in a position to understand them. As the Nipkow disc is the oldest form of scanning device, yet also one of the most efficient, we feel it will be of profit to study it first.

The Aperture Disc

We have already discussed briefly the size of aperture used in a 45-line disc of various dimensions, and also the fact that the scanned area is not square but keystone in shape. (See Figure 1.) Let us put out calculations on a little more general basis. It is evident that only one hole of the disc must be exposed at one time, the others being cut off by a suitable aperture. Therefore, the distance between the apertures or the width of the picture will be equal to:

$$w = \frac{2\pi r}{n}$$

where r is the radius of the disc to the hole, and n is the number of lines. (In these examples we will assume that the hole is circular.)

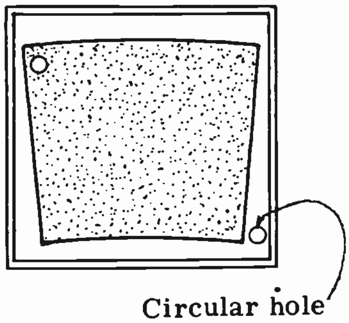


Fig. 1. "Keystone Effect"

The distance of the holes from the center obviously changes from hole to hole, so that the picture is wider at the top than at the bottom. Further, it is bounded by an arc both at the top and bottom so that the area swept out in scanning takes the form of a keystone. As the holes are to be circular, it is evident that the diameter of the hole must be equal to the width of the picture divided by the number of lines. As the width varies from the top of the picture to the bottom, we must use the mean width in calculating the size of the aperture. For instance, suppose that we have a 45-line disc which is 17 inches in diameter. We will assume that the mean radius (radial distance from center of the disc to the center of the picture) to the scanning holes is 7 1/2 inches; the mean distance between apertures will then be:

$$w = \frac{2\pi \times 7\ 1/2}{45}$$

$$= 1.03 \text{ inches (approximately).}$$

To find the diameter of the hole required, we must divide once more by the number of lines:

$$\text{diameter} = \frac{1.03}{45}$$

$$= .022 \text{ inches (approximately).}$$

The height of the picture will be the number of lines times the hole diameter because the holes must scan out adjacent strips. Thus, for this disc the height of the picture will be 45 x .002 inches or 1.03 inches (the same as the mean width of the picture). Assuming that the radius at the top of the picture is equal to approximately 8 inches, then the width will be:

$$\frac{2\pi \times 8}{45}$$

= about 1.1 inches

At the bottom of the picture the radius will be about 7 inches so that the width of the picture at this point will be:

$$\frac{2\pi \times 7}{45}$$

= .92 inches (approximately).

Thus, by very simple calculations we can ascertain the value of the various elements concerned.

Let us assume that we wish to construct a 180-line, 36-inch scanning disc, and are required to find the various parameters. As the radius of the disc is 18 inches, the mean radius will be about 1 inch less than this or 17 inches. The mean width of the picture will therefore be:

$$\frac{2\pi \times 17}{180}$$

= .58 inches(approximately).

We find the diameter of the holes required by dividing once more by the number of lines, so the diameter equals:

$$\frac{.58}{180}$$

= .0032 inches (approximately).

This is a very small hole and the illumination of the spot on the screen must necessarily be small. Notice how the diameter has decreased by increasing the number of lines from 45 to 180 even though the diameter of the disc has been more than doubled. Now that the amount of light reaching the screen is a function of the area of the aperture, and as this is equal to r^2 where r is the radius of the hole, then the light transmitted obviously has been decreased enormously.

The height of the picture is equal to the mean width, or, as calculated above, .58 inches. The width of the picture at the top can be found when it is remembered that the radius at that point is equal to the mean radius plus one-half the picture height, or 17 + .58/2, or 17.29 inches. The width of the picture at the top will therefore be:

$$\frac{2\pi \times 17.29}{180}$$

= .59 inches (approximately).

The illumination afforded by a flat plate type neon glow lamp such as has been extensively used in the past is but 1.5 lux. With from 30 to 45 lines, the picture formed with such a lamp is acceptable under certain circumstances, but when the number of lines reaches 180 or more the light passing through the apertures becomes almost negligible. The amount of light passing through the aperture must obviously be proportional to its area or $d^2/4$. We have seen that the diameter of the apertures used in a 45-line disc of 17-inches diameter is .022 inch. When 180 lines are used, even though the size of the disc has been more than doubled, the hole is but .0032 inches. The amount of light transmitted is therefore decreased, the ratio of light transmissions being $(.02)^2$ to $(.003)^2$ or 4 to .09. Thus, the one system is about 44 times more efficient than the other.

The exact relationship between the various parameters of the scanning disc and the amount of light which represents the picture is:

$$\text{Light output (lumens)} = \frac{\pi^3 B D^2 C_t}{4 n^4 k^2}$$

where B is the brightness in candles per square cm. (stilb), D is the effective diameter of the scanning disc in cms., C_t is the transmission loss coefficient, n is the number of lines, and k is the aperture ratio or the f-number of the system.

Calculating the efficiency or the light output of one of these systems is rather tedious, but it is useful in many ways. Let us calculate the light output for the 45-line disc we have discussed above. In addition to the values already given, let us assume that an intense source of light such as an arc is used which provides us with a brilliancy of 10,000 stilb. Also, that the transmission coefficient is equal to .4 and that the f-number of the system is equal to 5. The mean diameter or the effective diameter of the disc is equal to 15 inches or 37.5 cms.: Therefore we substitute in the equation as follows:

$$\text{Light output} = \frac{\pi^3 \times 10{,}000 \times 37.5^2 \times .4}{4 \times 45^4 \times 5^2}$$

$$= 0.426 \text{ lumens (approximately).}$$

Thus, if the picture is 1 meter square, the illumination would be 0.4 lux. However, the illumination can be greatly increased by decreasing the size of the picture to say about 10 cms. square. If this were done then the area of the picture would be decreased about 100 times and therefore the illumination would be increased about 100 times, or would be equal to 426 lux. In fact, such a value is seldom approached in practice, because if an arc light is used the light valve necessary to modulate it would make the total loss coefficient less than .4.

On the other hand--if a modulated glow lamp was used, the brilliancy would not approach such a high value as 10,000 stilb. The example does, however, serve to illustrate the efficiency that can be expected with an aperture disc system.

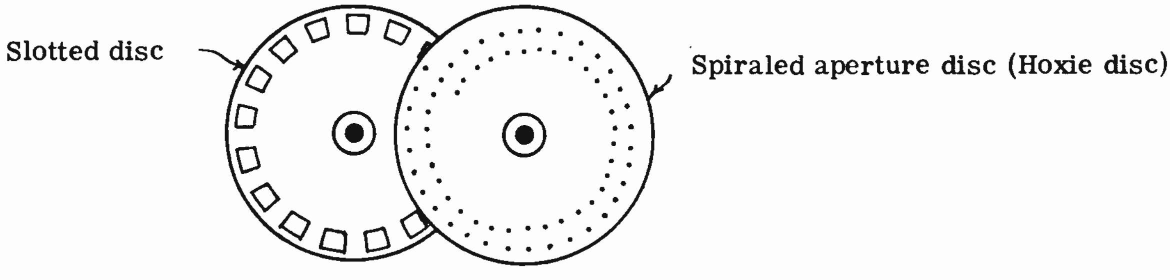


Figure 2.

These calculations apply to both the sequential scanner and the interlaced scanner. The order of scanning does not affect the optical efficiency. It does however materially affect flicker of the picture. Various types of scanning are discussed in a following assignment on television image characteristics. Interlacing requires the use of several spirals of holes none of which completely scans the image. In the three-spiral disc used by A.T.L. in its early experimental developments each of the spirals covers an angle of 120°, in other words extends around 1/3 of the disc's circumference. A different type of multi-spiral disc which is not used for interlaced scanning but affects the disc size is that invented by Hoxie in 1924. This disc arrangement simply consists of several spirals, each of which extends entirely around the disc (Fig. 2). Each one of them, however, is displaced along the radius so that the disc must revolve several times for one picture frame. The holes are displaced laterally by a distance equal to the picture width just as in the case of the simple spiral discs. In order that light from only one hole strikes the screen at one time, a defining aperture must be used with the disc to cut off all but one spiral. This aperture can move up and down as the disc rotates. A variation of this arrangement is one which used a slotted drum or disc. The light source is placed inside the drum or behind the disc, and the slots allow light to fall upon only one aperture of the disc at one time. The size of the scanning hole increases with the number of spirals. If there are three spirals or five spirals, then the holes can be three or five times as great as those of the simple disc. The area of the holes will then increase by a factor of 3^2 or 5^2 or 9 and 25 respectively. As the light from the source must now cover several spirals instead of one, however, there is no light efficiency gained in spite of the increase in aperture size. The only advantage then, is that the disc size can be reduced as the number of spirals is increased, i.e., if there are two spirals the disc will be one half as large, if there are four spirals the disc will be one fourth as large. Schroter developed several devices which allowed all of the light to fall upon one spiral when that spiral was being used, and thus gained light efficiency as well as disc size efficiency with a multi-spiral disc. One of these devices utilized a cylindrical lens drum in conjunction with the multi-spiral disc. You will remember that a cylindrical lens forms a line image of a point source. If the source has an appreciable area, then an elongated rectangle of light will be formed by the lens. These lenses were arranged in the drum so that the light would cover just one spiral of the scanning disc at one time. Both the drum and the disc were run with synchronous motors. It has been found that such a device becomes practically useless when more than 100 lines are required.

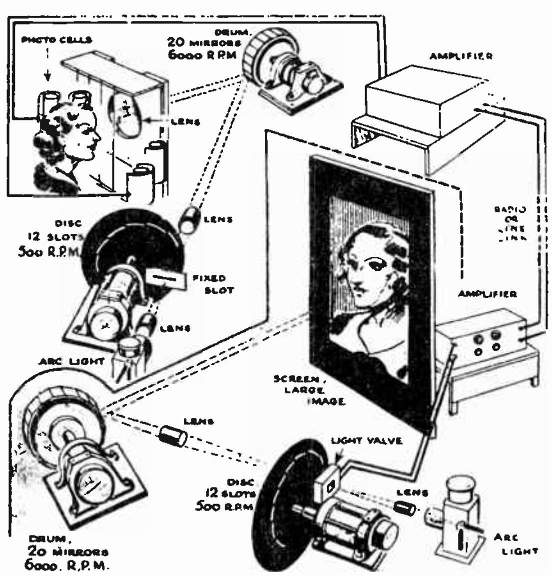


Figure 3.

There are many different combinations of scanning arrangements which use scanning discs of one form or another as an integral part of their construction. One of these devices which achieved some importance was that used by Baird in his so-called multi-mesh system. A combination of slotted disc and a mirror drum was used; the former served to execute the frame scan while the latter performed the line scan. In practice the drum consisted of 20 mirrors which revolved at a speed of 6,000 r.p.m. while the disc had 12 slots and revolved at 500 r.p.m., (See Fig. 3). The scanning was performed in a vertical direction in contrast to the practice which had been adopted in Germany and the United States of scanning in the horizontal direction.

There is a definite advantage in using separate members for scanning the lines and the frames of the picture. For instance, if an aperture disc and a mirror drum are used for scanning, the number of holes in the disc need no longer equal the number of lines in the picture. (See Fig. 4). If it is assumed that the

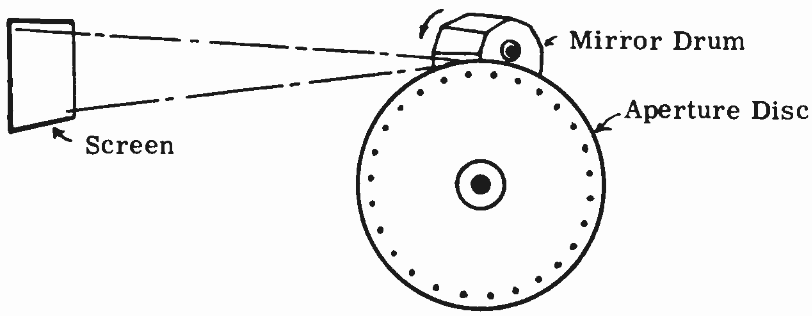


Figure 4.

mirror drum performs the frame scanning while the disc performs the line scan (which must be the case if an aperture disc is used in contrast to the condition if a slotted disc is used), then the disc may revolve several times for each frame. For instance, if there are to be 100 lines in the picture then a disc having but 10 holes could be used which revolves 10 times per frame. If the number of holes in the disc is equal to q and the number of revolutions per frame is equal to p, then pq must always be equal to the number of lines in the picture. This is in marked contrast to the single spiral disc where q must equal the number of lines. In this way the size of the disc may be materially reduced while the size of the apertures can be appreciably enlarged. This effects a considerable saving in space, power required, and light efficiency. It can be shown that the light efficiency goes up at p^2 so that a small high speed scanning disc for line scan purposes has very definite advantages. It was the practice to use high speed discs in this manner and to run them in an evacuated chamber. The latter practice both eliminates the possibility of dust entering and obscuring the apertures as well as materially reducing the amount of power required to drive the scanner at these speeds. A 4 foot aperture disc has been described which revolves at 12,000 r.p.m. It was found that 2 horse power was required to drive the scanner. Much smaller scanners are the rule, however, and the power required decreases proportionally.

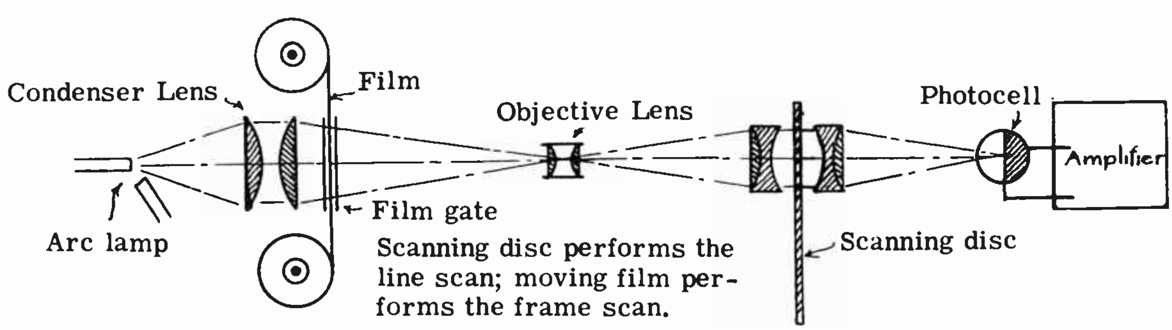


Figure 5.

When films are to be transmitted, the movement of the film itself can constitute the frame scan. Thus, an aperture disc having but a circle of holes can be used. (See Fig. 5.) With this arrangement, just as in the case of using the ordinary type of frame scanner, the aperture disc can be rotated at several times the frame speed with great advantages. This fits in very well with the type of motion picture projector machines used in Europe in which the film does not move intermittently, but continuously. When machines such as used in England and the United States are used, the intermittent character of the film movement requires some arrangement for frame scanning. This may take one of various forms such as the multi-spiral disc or the combination of slotted discs, etc.

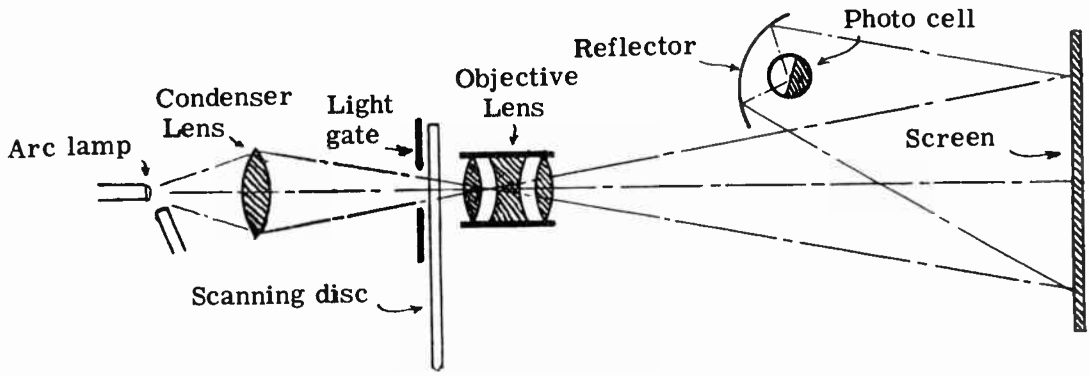


Figure 6.

When either separate frame and line scanners are used or a film transmitter such as that described is used, the driving means must be properly locked into step with one another. Furthermore, they must be capable of being controlled as one unit by synchronizing pulses. The use of high speed scanners has very great advantages from several view points. From the angle of driving means, however, the situation is very different. In Europe the standard frequency for power lines is 50 cycles per second, while here in the United States it is 60 cycles per second. A two-pole synchronous motor will revolve once per cycle so that at 50 cycles per second, the motor would revolve 3,000 r.p.m., while at 60 cycles per second it would revolve at 3,600 revolutions per minute. When greater speeds are desired, it is usually necessary to use some frequency multiplier device or a special type of gearing such as a Burn form of Watt silent gear. When the multiplier is used, it entails additional apparatus, and when the gearing is used, special attention must be paid to the design so that back lash or slippage does not occur. With gearing in particular it is difficult to prevent the speed from oscillating about a certan point which of course, results in the picture see-sawing back and forth across the frame. These difficulties had been, however, largely overcome, and was possible to obtain very good pictures with dual scanning arrangements.

There are two methods of using the scanning disc at the transmitter. One of them is called direct scanning while the other is called indirect scanning (Fig. 6), and while they have identical efficiencies if the component parts are identical, there is a definite advantage in using the indirect method whenever possible. The stages by which the light reaches the photo-cell from the source may be tabulated as follows:

FLYING SPOT INDIRECT SCAN	DIRECT SCAN
1. Light from arc crater	Light from arc crater
2. First image in plane of scanner	First image in plane of subject
3. Second image in plane of subject	Reflection from subject
4. Reflection from subject	Light reaches objective
5. Light reaches reflector	Second image in plane of scanner
6. Light reaches photo-cell	Light reaches photo=cell

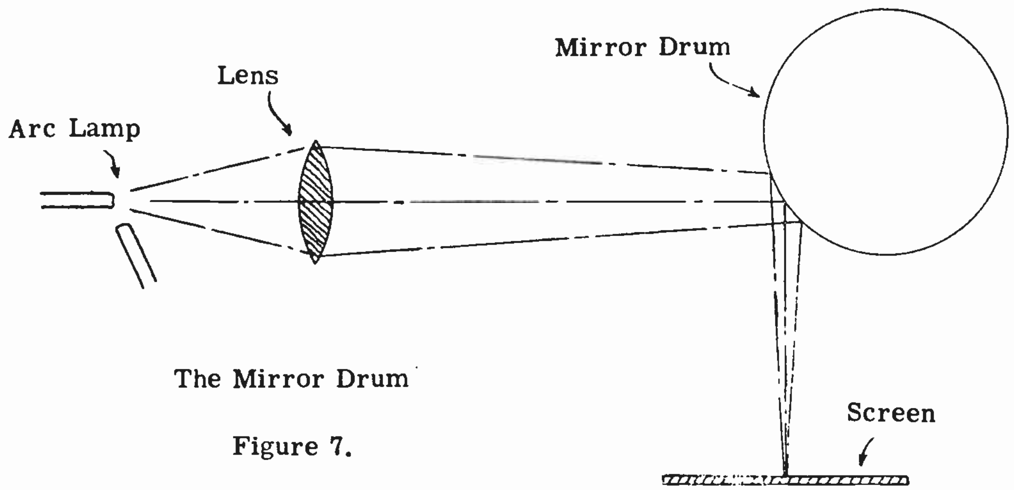
Now the difference in efficiency between these two systems lies in the fact that it is the amount of light collected from the subject that is important. Thus, the greater the angle subtended by the light gatherer at the subject, the greater will be the efficiency of the system. If the photo-cell and reflector in the indirect system were placed as far away as the objective lens in the direct system and it had the same diameter, then the efficiencies would be the same. There is a definite limit, however, to the distance at which the objective can be placed, and also to the aperture of the objective. If the efficiency is to be reasonable in the indirect system, a very wide aperture, short focal length objective must b e used so that the lens subtends a large angle at the subject. Now it must be obvious that a reflector and a photo-cell can be made much larger and placed much closer to the subject than can an objective lens. What is more, the cost would be much less. Thus, in practice a reflector can subtend a much larger angle at the subject than can any objective lens and therefore the indirect system is much more efficient. We can express the ratio of the efficiencies of the two systems directly in terms of the solid angles that the two types of light collectors subtend at the subject. These solid angles are proportional to the square of the radius of the light gatherer and the square of the distance between it and the subject. Thus, if we denote the radius of the objective by r, the radius of the reflector by R, the distance of the objective lens from the subject by l and the distance of the reflector by L, then the efficiency of the indirect scan is to the efficiency of the direct scan as $R^2 L^2$ is to $r^2 l^2$.

Let us take an example: Supposing that we have a reflector which is 8 inches in diameter and placed 24 inches from the subject. Also, that our objective lens is 1 inch in diameter and 36 inches from the subject. The ratio of the efficiencies will then be:

$$\frac{R^2 L^2}{r^2 l^2} = \frac{4^2 \times 24^2}{.5^2 \times 36^2} = 28.425$$

Thus the advantage is extremely large.

Several years ago, before the caesium cell had reached such a high state of perfection, television engineers were forced to build very large photo-electric cells to obtain reasonable output. One of these "monsters" was built by Dr. Lloyd P. Garner for U.A. Sanabria. It was over 16 inches in diameter. The cell was of the potassium hydride type which had proven many times in the past to be most satisfactory when a neon reproducer lamp is used. The combination of the color



The Mirror Drum

Figure 7.

in the past to be most satisfactory when a neon reproducer lamp is used. The combination of the color sensitivity of the potassium type of cell and the color response of the neon type of glow lamp is such as to so counter balance that the proper tonal shading results. In fact when a neon glow lamp was used the potassium type of cell rendered better tone value than a caesium cell, though of course, it is inferior to the latter in sensitivity. The large type of photo-cell was of course extremely efficient as far as the indirect scanning method was concerned. If the cell was placed reasonably close to the subject, it is evident that a very large amount of light would be collected. Owing to the enormous cost of such a cell, however, its manufacture has been discontinued.

We have discussed in a previous assignment the simple mirror drum which uses as many mirrors as there are lines in the picture and which has the mirrors tilted so that they perform both the line and frame scanning. The area of each mirror and therefore the size of the drum, increase when we attempt to increase the efficiency of the system by passing more light through it. An expression which allows us to calculate the efficiency of the mirror drum or rather allows us to calculate the illumination of the screen of any given size when we know the various parameters of the system is that equation derived by Dr. Moller who is well known for his work in the television field in Germany. This expression is:

$$I\ (\text{lux}) = \frac{1.6 \times 10^5 \pi^2 M C_t B}{l\, b\, n^4}$$

where M equals area of each mirror on the drum, C_t is the transmission coefficient of the system, B is the brightness of the source, l is the length of the picture on the screen, b is the breadth of the picture on the screen, and n is the number of lines in the picture.

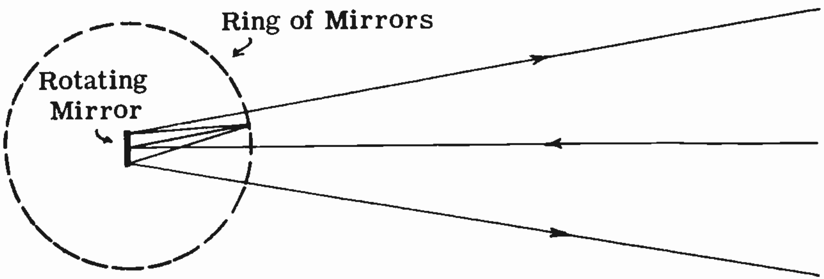


Figure 8.

Suppose that we wish to find the size of the mirrors required for a receiver in which the minimum allowable illumination of the screen is 1.5 lux (if a ground glass translux screen is used the apparent illumination will be about ($\pi \times 1.5$) or 4.5 lux. The brightness of the light source is assumed to be 2,000 stilb. The transmission factor we can assume to be about .33. This low figure is mainly due to the optical inefficiency of the light valve. In fact this value is a very fair one as in many receivers it is much less. We will assume a picture length of 40 cms. and a picture breadth of 30 cms. Then as π^2 is approximately equal to 10, we find that the area of the mirror is equal to:

$$3/2 \times 4/3 \times n^4 \times 900 \times 1/ 1.6 \times 10^5 \times 10 \times 1/3 \times 2{,}000)$$

$$= \frac{27n^4}{1.6 \times 10^7}$$

Let us assume that the mirror is square, then the linear size of the mirror will be:

$$\frac{3\sqrt{3}\ n^2}{4 \times 10^3}$$

The circumference of the drum will be approximately equal to:

$$\frac{n \times 3\sqrt{3}\ n^2}{4 \times 10^3} = \frac{3\sqrt{3}\ n^3}{4 \times 10^3}$$

As the diameter of the drum is equal to the circumference divided by π it will equal $n^3/2{,}500$ cms. Now if the picture is very low definition, say 30 lines, then the diameter of the drum will be:

$$\frac{30^3}{2{,}500} \text{ cms. or } 10.8 \text{ cms. (Approx.)}$$

This is a reasonable diameter if the drum rotates 25 times per second (25 frames per second) or 1,500 r.p.m., then a disc of 10.8 cms. will be quite within practicability.

If the number of lines is increased, however, an entirely different situation exists. Suppose that we desire 100-line definition rather than 30, then the diameter of the drum becomes:

$$\frac{100^3}{2{,}500} = 400 \text{ cms.}$$

To even contemplate a four meter (over 12 feet) mirror drum rotating at 1,500 r.p.m., would be utterly fantastic. Thus, it is seen that to achieve even a comparatively low brilliancy with reasonable number of lines, the mirror drum is absolutely out of the question.

Suppose we look at the mirror drum problem from a slightly different angle. If we started out by limiting the size of the mirror drum to a diameter of 20 cms., what would be the result? For the 100-line definition picture the drum will be 20/400 or 1/20 of its theoretical size in linear dimensions, and the area of the rotating mirror M and therefore the illumination was as low as could be tolerated, so naturally 1/400 of this value would be an impossible one. Now in the above calculation, we assumed that the mirrors were square. This need not be the case, and an advantage is gained if the mirrors are quite a bit longer than they are wide so that the drum is much longer than its diameter. This is the arrangement used in the Scophony beam converter. However, to use a simple mirror drum of this type is impractical as can be readily shown. For instance, the area of the mirrors for 100-line definition (assuming the illumination stated above) must be:

$$\frac{27 \times 10^8}{1.6 \times 10^7} = 169 \text{ square cms.}$$

Now let us assume that the drum is confined to a diameter of 20 cms. The circumference would be about 60 cms. and therefore the mirror width would be 60/100 or .6 cms. Now comes the difficulty; we have found that the area of the mirror must be 169 square cms. As the width is to be but .6 cms, the mirrors must be 169/.6 = 282 cms. This immense length would make the mirror drum absolutely impractical. If the mirror drum was restricted to a 20 cms. length then the necessary illumination would be decreased to 1/14 of the proper value. From these examples we can see that a much more complex arrangement must be used if a sufficient illumination is to reach the screen with a mirror drum scanner of reasonable dimensions.

The first advancement in the way of overcoming the fundamental inefficiency of the mirror drum was taken by Mihaly. He devised a system that in effect allowed the mirror drum to remain stationary while a single mirror rotated. In practice his device took the form of a single mirror rotating in the center of a ring of mirrors equal in number to the number of lines desired. The ring mirrors are tilted so that the frame scan takes place just as the mirrors of the mirror drum are tilted to perform the same function. Light on traveling through this system first strikes the rotating mirror, then a stationary mirror, then the rotating mirror once again and finally to the screen. It persues a W shape through the system. (See Fig. 8) As the light must fall obliquely on the center mirror in a horizontal plane so as not to foul the ring mirrors before and after reflection, it is obvious that it must be larger than the ring mirrors. In practice it is about twice as high and twice as wide. The cone of light which passes to the screen is limited in extent by the smallest member of the scanning system. That is, the solid angle that is subtended by the smallest mirror in the system at the screen determines the efficiency of the system. In the Mihaly scanner the smallest mirror is located in the ring. The same equation applies to the Mihaly scanner as to the normal mirror drum, so that to obtain the necessary illumination of the screen we must once again have a mirror with an area of 169 square cms. for 100-line definition. As the limit is set by the ring mirror, each of the ring mirrors must have an area of 169 square cms. Suppose that they are twice as high as they are wide. The height will be 18.4 cms. and the width will be 9.2 cms. making the total circumference for the ring of 920 cms. (100 mirrors). This gives a diameter of approximately 300 cms. This is a definite improvement but it is still way out of reason with that which is required for a home receiver. As we have said before the central mirror must be about twice the height of the ring mirrors, and if the latter are 18.4 cms. high, then the central mirror must be 36.8 cms high. If it is twice the width also, it will be 18.4 cms. wide. As the mirror rotates through one half the former value for the mirror drum, the speed is halved, that is, it becomes 750 r.p.m. This factor is not prohibitive.

In the Mihaly system, the ring mirrors must be tilted so that the scan is performed in the vertical as well as the horizontal direction. As there must be as many ring mirrors as there are lines in the picture, the adjustment of these mirrors becomes a very exacting and tedious process. For these several reasons the Mihaly scanner in its original form is really impractical for television purposes. Traub has devised a modification of the Mihaly system which shows much greater promise. He replaced the single two-sided mirror in the Mihaly system with a mirror drum containing from 5 to 10 mirrors. (See Figures 9 and 10.) Further, the ring mirrors were reduced so that

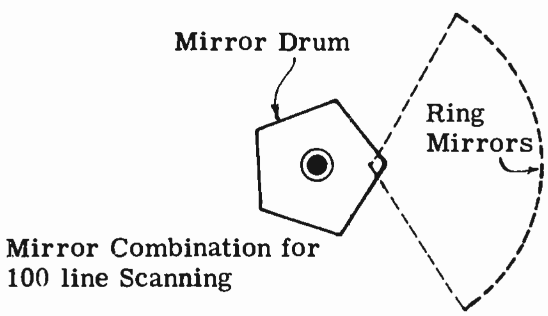


Figure 9.

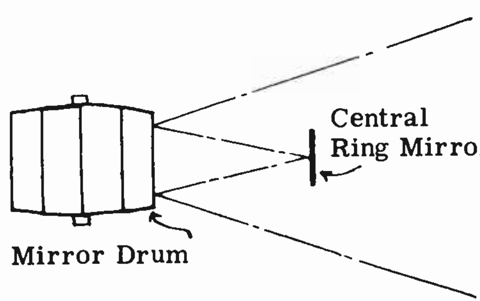


Figure 10.

they were no longer around the entire circumference of a circle, but only occupied a portion of it. Now the most obvious advantage of this system is that the ring mirrors need no longer equal the number of lines in the picture. If they are to be 100 lines, then only the product of the number of mirrors on the rotating drum and the number of stationary mirrors need equal 100. In one arrangement for instance, a 5-mirror rotating drum is used with 20 mirrors in the ring. In other words, if the number of mirrors on the drum is equal to N_d and the number of mirrors in the ring is equal to N_r, then $N_d \times N_r = n$ where n is the number of lines. When the formula is worked out for this system it is found that it is similar in form to the formula for the simple mirror drum except that a new factor of 4 is introduced. Thus, the system has four times the optical efficiency of the simple mirror drum. It can be shown that while the diameter of the ring of mirrors in the Mihaly system is obviously equal to the number of lines times the mirror width divided by π, only half this diameter need be used for the Traub system, and, of course, the whole circumference is not used (less than one half). Also, the mirrors in the ring need not be one-half as wide. However, less than half the ring is now required and as the circumference of the ring has been reduced by one-half, the overall linear size of the system has been to $(1/2)^3$ or 1/8 of the size of the Mihaly system. It has been found that the drum mirrors must be twice as large as the ring mirrors if there is to be a uniform scan all across the line. Therefore, in a 100-line system such as that considered a little earlier, the drum mirrors would be 9.2 cms. wide and therefore the drum would be about 15 cms. in diameter. As the drum must rotate once per picture, the speed of rotation will be 1,500 r.p.m.

Probably the greatest advance of all in mirror drum systems took place when the functions of the line and frame scanning were separated. In all of the mirror systems we have considered up to this time, frame scanning took place because the line scanning mirrors were tilted. Now we have seen in the consideration of aperture disc systems that there is a great advantage in using separate scanners for the line and frame scans. So, when mirror drums are used a much more efficient system can be arranged if one mirror system is used for performing the line scan and the other for performing the frame scan. This is called a ''crossed drum'' scanner, and it can be very profitably employed with a Mihaly-Traub arrangement. With this arrangement the number of lines need no longer be equal to the product of the number of drum mirrors and the number of ring mirrors. Thus, if there are to be 100 lines, the mirror drum performing the frame scan can rotate say 5 times per frame, the number of ring mirrors would be reduced to 1/5 of the number used previously. If the number of mirrors in the line scan arrangement is maintained the same, their dimensions can be reduced to 1/5 of their former size. Suppose, for example, the number of stationary mirrors in the 100-line scanning system previously considered is reduced to 4 and the line scanndrum rotates 5 times for each frame; the dimensions of the ring mirrors now become only 1.84 x .92 cms. while the mirrors on the drum are only 3.68 x 1.84 cms. The diameter of the drum required therefore is reduced to only 3 cms. and as it is so small it can be made from a solid piece of glass; therefore, when it is accurately made it need never be readjusted. The choice of 405 lines as a standard for this type of mechanical receiver is particularly fortunate. A 9 sided mirror drum is used with 5 stationary mirrors (See Fig. 11) so that to obtain 405 lines

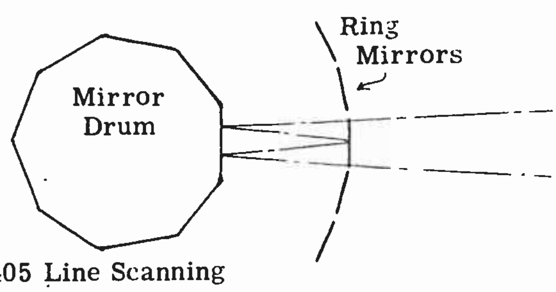


Figure 11.

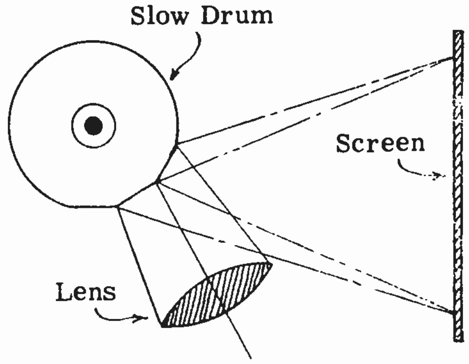


Figure 12.

the mirror drum must rotate exactly 9 times per frame, because 9x5x9 = 405.

We have seen from the formulae that the illumination of the screen is directly dependent upon the area of the mirrors. This is due to the fact that the illumination falling on the screen must necessarily be a function of the solid angle that the mirrors subtend at the screen. If, however, the light source could be imaged at the scanner, then obviously the size of the mirrors could be substantially reduced. If the source is imaged at the scanner, however, no movement of the spot across the screen occurs so that this method cannot be used under ordinary circumstances. A new type of light valve using the Debye-Sears effect enables us to use this system, however. Thus, apart from this light valve's advantages it enables an increase in efficiency in the scanner itself. This arrangement allows adequate brightness of the screen with almost any number of scanning lines.

It is interesting to compare the Mihaly-Traub system with ordinary crossed mirror drums. We have seen in the above paragraph that a Mihaly system producing 405 lines must have its high speed scanner rotate 9 times per picture. If there are to be 1,500 pictures per minute (25 pictures per second) than the high speed scanner must rotate at a speed of 9 x 1,500 or 13,500 r.p.m. However, a simple drum rotating at this speed would require 45 mirrors. Furthermore, the scanning angle of the drum would be only half that of the Mihaly-Traub scanner. If a 9 sided simple mirror drum was used it would have to rotate 45 x 1,500 or 67,500 r.p.m. The advantages of the latter system are obvious. The frame scanner can be of much larger dimensions than the line scanner because it is traveling at a much smaller speed. The larger size enables larger mirrors to be used, and consequently the illumination of the screen is increased.

It has been determined that to obtain really adequate illumination of the screen with a mechanical system the line scanner should revolve at not less than 20,000 r.p.m. Such speeds are easily obtained when the rotating member is driven by air pressure or by some electrical means in which bearings are not required. The diameter of the scanner must of course be kept small. It is estimated that up to 12,000 r.p.m. the diameter must not exceed 10 cms.; for speeds up to 40,000 r.p.m. the diameter should not exceed 5 cms.; and for speeds over 40,000 r.p.m., the diameter must be kept down to 3 cms. In the Mihaly-Traub scanner described above the line mirror drum has a diameter of 3 cms. and it rotates at 13,500 r.p.m. so that these requirements are quite within the realm of practicability.

A lens must be used between the line scanner and the frame scanner so that an image will be formed upon the screen. (See Fig. 12.) The lens must be between the scanners and not between the slow drum and the screen because the size of the lens is limited. If it follows the slow drum, it must cover the whole angle containing the widely divergent rays which pass to the screen. When it is placed between the drums, the lens must not restrict the amount of light passing between them, and therefore must be larger in diameter than the slow drum mirror. In many systems a 12-mirror slow drum is used which has 6 cm. mirrors and the device rotates at 250 r.p.m. The illumination of a screen 40 x 30 cms. when a Mihaly=Traub crossed drum scanner is used has been calculated for various values. If a light source having a brilliancy of 2,000 stilb is used, and a transmission facter of 1/3 is assumed, the other dimensions being the same as those mentioned above, the illumination is 3 x this value or approximately 7.5 lux. This is usually considered adequate.

Intermediate Film Systems

A rather novel arrangement has come into quite wide popularity in Germany in the last few years. This is called the intermediate film system and it is used both at the transmitter and at the receiver. (See Figure 13.) At the transmitter a moving picture camera takes photographs of the scenes to be transmitted and the film is immediately developed and run through a special film scanning arrangement and then the film is stripped, recoated with emulsion and fed once more to the camera. Thus, a small amount of film can be used over and over again. In practice a complex

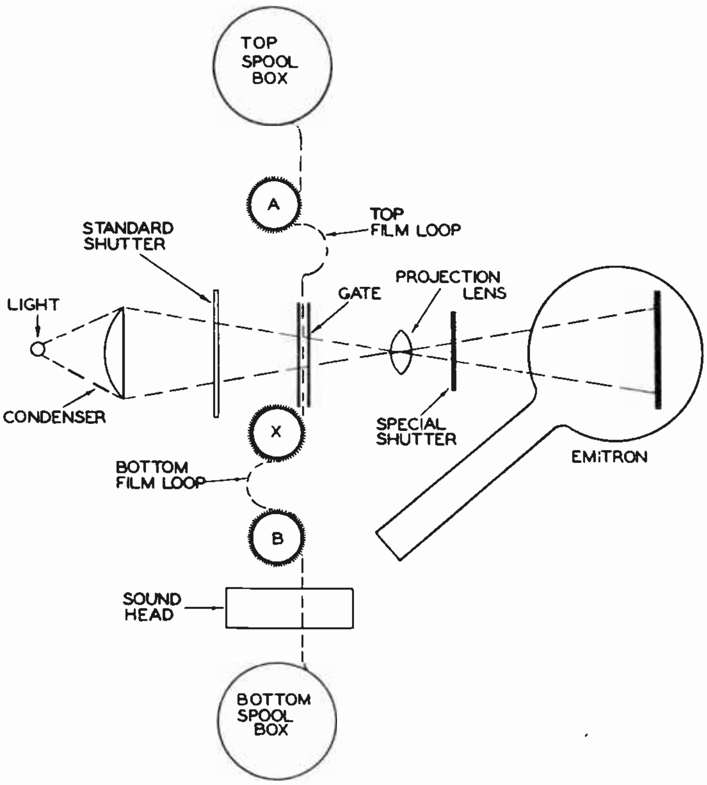


Figure 13.

arrangement of baths and dryers is used together with a continuous length of film. The very widest aperture lenses are used in the motion picture camera to obtain good contrast in the film so that it can be transmitted satisfactorily. Usually aperture disc scanners are used to perform the line scan while the movement of the film itself performs the frame scan. However, many variations in the methods of scanning have been used. One of the better known of these is the Scophony film transmitter. At the receiver the same scanning arrangement is used as at the transmitter. In this case light from a powerful arc is used to scan and therefore darken the film which is then developed and the picture is thrown on the screen by means of a conventional type of projector. The intermediate film transmitter is quite practical for nearly every television use while the receiver is only practical for theaters because its large size prohibits its use in the home. The main problem at the receiver is to obtain satisfactory blackening of the negative, and much research has been done in the way of developing super-sensitive films which are suitable for rapid development. When sound is to be transmitted as well as pictures, it is obvious that the sound must be delayed the same length of time as the pictures. The easiest way of accomplishing this is to record the sound on the film just as is the practice with sound movies.

To get a clear picture of the manner in which the intermediate film receiver operates, let us trace the motion of the film through one of these devices as illustrated in Fig. 14. The film passes through the aperture gate B where it is scanned by the light originating at the arc A and passes through the scanning disc, C. After it has been acted upon, it travels through the developing, fixing, and washing baths placed at F. From there it travels on through the projector gate E and light originating at the second arc D passes through the film and the picture is thrown on the viewing screen. From E the film passes through the baths placed at G which remove its emulsion, then passes underneath the assembly where it is dried and thence to I where it is recoated with emulsion and ready for use once more. It passes from I back again to the aperture gate B and the action goes on like before. The illumination of the film will be similar to that with the ordinary scanning disc arrangement except that as the frame scanning and the line scanning is performed

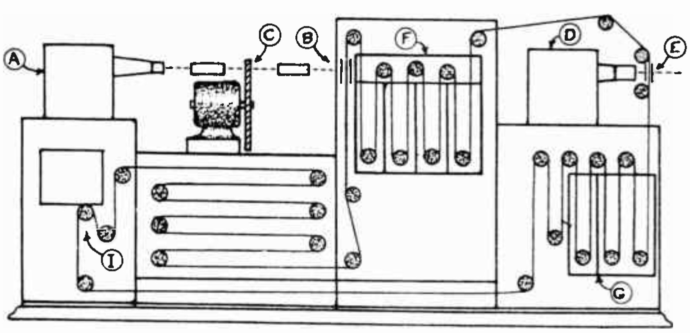


Figure 14.

independently, the disc can be run at several times the usual speed. That is, the disc can rotate several times per frame and the illumination will be increased accordingly. You will remember from the previous paragraph that the illumination increases as the square of the number of revolutions that the disc makes per frame.

Baird Film Transmitter

Let us look at the construction of the Baird film transmitter which is used commercially in England at the present time. We can describe it as follows:

The film processing section consists of a tank divided into six compartments, each compartment being used for one stage in processing the film. These compartments are: (1) developing; (2) washing; (3) fixing; (4) washing; (5) scanning; and (6) outer jacket containing warm water to maintain the developer and fixing compartments at the correct temperature.

The film drive, sprockets, motion picture camera, sound recording camera, and sound reproducer head, are mounted on a framework which raises and lowers the film into the tank by means of a pnuematic jack. This makes the operation of threading the film very simple.

The subject to be televised is photographed on 17.5 mm film (half standard 35 mm film) with a motion picture camera of the intermittent type, mounted directly above the developing compartment. The film passes through the camera at a rate of 46 feet per minute, the whole unit being driven by a synchronous motor running at 1,500 r.p.m. The film, coated with a rapid and sensitive emulsion, after passing through the picture camera is fed to a sound recording camera situated immediately below, where the sound track is recorded between the perforations and the edge of the film. After leaving the recording camera, the film passes into the developer, is washed, after which it is fixed. It is then finally washed and passes into the water-filled scanning compartment, where it runs over a guide.

The complete operation takes only thirty seconds from taking the picture to transmission by radio.

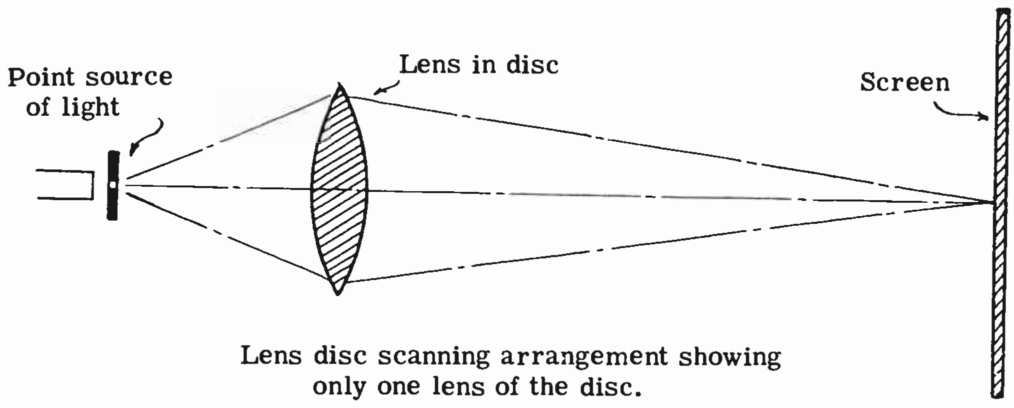
A beam of light from an automatic mirror arc lamp is focused through the window in the scanning compartment onto the slit in the guide. The image of the moving film passing over the guide is projected by the lamp on to the scanning unit through a combination of lenses. The scanning unit consists of an encased scanning disc having a circular trace of sixty apertures. This disc revolves at 6,000 r.p.m., i.e., four times every picture frame, so as to provide a 240-line picture dissection. This high speed enables larger apertures to be used than would otherwise be possible, giving a material increase in available light. The disc is driven by a water-cooled synchronous motor. Both the motor and the disc are run in vacuum, the whole unit being evacuated by a single-stage pump with a mercury contactor so arranged that it is impossible to start the disc until the vacuum is attained.

The water-cooling of the synchronous motor is linked up with the sprays in the washing compartment, the supply being taken from the water mains. In the event of water failure, a water-cut-out operating through a relay, breaks the electric supply to the disc motor before any possibility of damage can occur. It is also impossible to start the scanning disc before the water is circulating through the cooling system of the motor.

The Lens Disc Scanner

The lens disc is one of the oldest forms of scanning devices, but it has almost vanished from the television scene except in some types of receivers and various modifications which are used for film scanning at the transmitter. If we assume that we have two systems, one a lens disc and the other an aperture disc arrangement, then providing that all the conditions are identical the efficiencies of the two are identical. This sounds extremely strange at first until one realizes that under normal circumstances the conditions under which the two are operated are not identical or anything like identical. For instance, when the lens disc is used at the receiver, a point source of light is used and an image of this point source is projected onto the screen. The amount of light that passes from the one source to the screen will depend upon the diameter, naturally, larger diameter--more light. Now in the case of the aperture disc a light source large enough to cover the whole picture aperture must be used. If it is not used then a lens system must be used which has sufficient magnification to fill the picture aperture with light. If the source is as large as the picture aperture and as brilliant as the point source used in the lens disc system, then obviously their efficiences will be the same. It is usually impractical, however, to use such a large light source as would be required, so that a condenser system must be used. Therefore a majority of the light, in fact all of the light filling the aperture of the picture except that passing through the aperture is wasted. In the case of the lens disc, however, all of the light emitted from the source within the angle subtended by the area of the lens passes to the screen and therefore at the receiver the lens disc has very great advantages. In the realm of low definition pictures it has a definite place, however, when the number of lines increases up to 200 or 300 or more the lens disc must give way in efficiency to the high speed mirror systems.

The various parameters of the lens disc are determined in much the same fashion as those of the aperture disc. If 45 lenses are to be used, then they will be spaced 360/45 or 8^{o} apart. They will be displaced from one another along the radius by a distance equal to $2\pi r/n^2$ where r is the mean radius of the picture, and n is the number of lines. The lenses are made just as large as can be accommodated by the disc employed. Naturally, the larger the disc the greater the size of the lenses that can be used and the greater the efficiency of the system.



Lens disc scanning arrangement showing only one lens of the disc.

Figure 15.

A special type of lens disc receiver has been developed by A.T.I. for special use in theaters, etc. The disc has a diameter of 24 inches and is equipped with 45 lenses each having a diameter of 1 1/4 inches. The rise between the lenses is .031 inches (the rise is the distance that each lens is displaced from the other along the radius.) A modulated carbon dioxide crater type lamp is used which produces substantially black and white pictures.

Various modifications of the lens disc have been employed in the past for scanning purposes. One of these modifications is the lens drum which is analogous to the aperture drum and like it has little advantage over the original arrangement.

A type of lens drum which is used in some film transmitters has, however, definite advantages.

In this device the light passes through lenses in the drum twice. As the two lenses at the opposite sides of the drum are traveling in opposite directions, the speed of the scan will be doubled. That is, the efficiency will be similar to the case of a lens disc traveling at twice the speed. This is the principle used by Baird in his so-called optical lever system. Now it must be evident that when the lenses are at either the beginning or at the end of the scan so that they make quite an angle with the light which passes through them, a lot of the light which passes through the first lens will not pass through the second, but will be cut off by the drum. To overcome this difficulty a so-called field lens, F, (Figure 16) is placed at the center of the drum to make sure that all of the light from the first lens will pass through the second lens. Now, however, we have the difficulty of distortion. We have seen in previous assignments that when light is incident on a simple spherical lens the typical aberrations of the sky rays will show themselves. These aberrations are coma, astigmatism, and curvature of field. The first two of these aberrations will cause blurring of the spot automatically while the third aberration will simply cause the spot at the screen to be out of focus in some positions. For instance, if you were inspecting the raster built up by such a scanner, the lines would be found to be small in width and in focus at the center but quite wide, blurred and fully out of focus at the sides of the picture. To overcome this difficulty a sphere of glass is used rather than the usual type of lens, and the focal length of the lenses in the drum are arranged so that they bring the light to a focus at the center of the sphere. (See Figure 17). This has been found to overcome the difficulties described. In any lens scanner system the lenses in the drum or in the disc form the final objective of the system. That is, these lenses form an image at the screen or in the case of a film transmitter, at the film. When the optical lever system is used, the functions of line and frame scanning must be separated as it has not been found practicable to stagger the lenses in the drum to perform the frame scan. Advantage can be taken of this fact and the line scanner can be rotated several times per picture. Just as in the case of the other types of scanners when this principle is used, the efficiency of the system increases as the square of the number of revolutions of the line scanner per picture. We have seen that the speed of scan is doubled by using the optical lever principle so that the total efficiency is $2p^2$ times as great as the simple lens disc or aperture disc. The symbol p refers to the number of times the line scanner rotates for each picture.

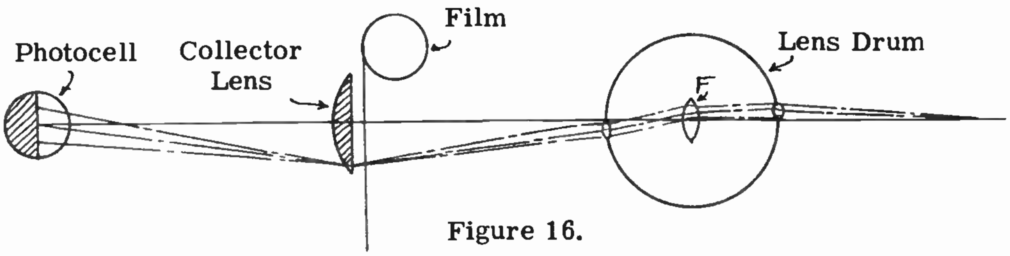


Figure 16.

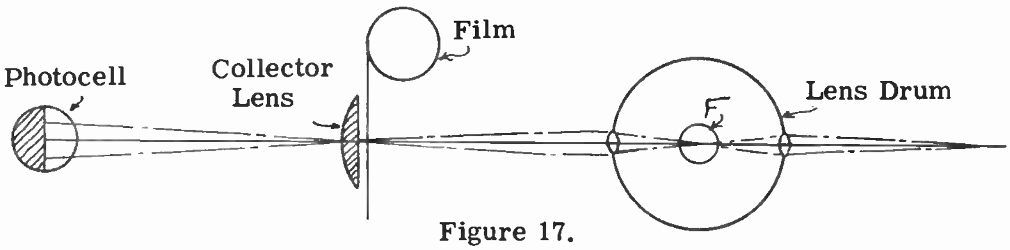


Figure 17.

Now let us summarize the efficiency of the various systems. We have seen that the light output in lumens from an aperture disc scanner may be expressed as:

$$\frac{\pi^3 BD^2 C_t}{4n^4 k^2}$$

Let us for brevity in comparison call this quantity A. Further, we have seen that the illumination from a simple mirror drum can be written as:

$$\frac{1.6 \times 10^5 \pi^2 MC_t B}{lbn^2}$$

Let us for brevity call this expression M. Then we can list the efficiencies of the various other systems in terms of these two oldest and most fundamental systems as follows:

Crossed mirror drum	$4M$
Mihaly-Traub	$2q^2M$
Mihaly-Traub crossed drum	q^2p^2M
Lens Disc	A
Combination of lens disc and mirror drum	$\frac{p^2A}{2}$
Multiplying lens drum	$2p^2A$
Aperture disc film transmitter	$\frac{p^2A}{4}$
Multiplying lens drum film transmitter	$4p^2A$
Mihaly-Traub film transmitter	$2q^2p^4M$

In the above expressions p is equal to the number of revolutions of the line scanner per picture, while q refers to the number of ring mirrors in the Mihaly-Traub system. You will notice that when either the multiplying lens drum (the optical lever arrangement) or the Mihaly-Traub system is used as a film transmitter, the efficiency is twice as great as when it is used in the normal manner. The reason for this is that the film itself performs the frame scan, and so no loss of light can occur similar to that occurring when a mirror drum is used for frame scanning. It is estimated that one-half the light is lost at the frame scan or slow mirror drum. Therefore when these systems are used as film scanners the efficiency is just doubled. Notice the gain in efficiency when crossed drums are used with the Mihaly-Traub system. We feel it safe to say that the greatest single advantage in mechanical scanning occurs when separate scanners are used for the line and frame scans. The gain in light output over the older method is truly phenomenal.

There are two systems of scanning which we have not as yet mentioned because of their comparative unimportance. However, we feel that the reader should at least know what they are in case they are mentioned. The first of these systems is called the split beam system and it consists of an arrangement of a simple mirror drum and a so-called beam splitting optical system.

Suppose for instance, that we had a simple mirror drum suitable for 30 line scanning, and then some optical system was used to split up each of the 30 lines into 8 sections. Then the raster would consist of 240 lines which is a comparatively high definition system. This arrangement has an apparent efficiency of twice the square of the number of mirrors used to effect the splitting of the line scan. In practice, however, it has been found that the device is inferior to even the simple crossed drum mirror system, and consequently with such rivals as the Mihaly-Traub crossed drum system the device has fallen into disuse. A variation of this system has been experimented with at A.T.I. A mirror was used at the transmitter and receiver of an aperture disc system to cut the line scans in half and reflect one-half of the line a short distance below the other half. In this way the apparent definition of the picture was doubled, but the picture raster of course was only one-half as wide. A cylindrical lens can be used to bring the raster back to its original shape, but if the definition of the picture is to be consistent with the number of lines, the holes must be reduced to one-half of their size and so no gain in optical efficiency actually results. For these reasons this experimentation has been discontinued. In a previous assignment we have mentioned the concave mirror disc which has several apparant advantages over the lens disc. Systems have been constructed which use the concave mirror disc to perform the line scan and a mirror drum to perform the frame scan. One of the fundamental disadvantages of the mirror disc is the fact that light should be incident upon and reflected from the mirrors in the same straight line which of course is very difficult to accomplish in practice. The reason that this should be so is self evident. If the light falls upon the mirror at an oblique angle or is reflected from it at a very oblique angle, numerous distortions of the spot will occur such as spherical aberration, coma, etc. Furthermore, the efficiency of the reflecting surface seriously diminishes with the angle of incidence. In fact, we have mentioned before that right angle prisms are used when a 45^{o} reflector is required in most optical instruments. If it is attempted to use only a small angle of incidence to the mirrors, it is very difficult to keep components of the rest of the optical system from interfering with the cone of light falling on the mirrors. Of course, this seriously limits the amount of light that can be used, which in turn seriously decreases the efficiency of the system. From these and other reasons the concave mirror disc scanning system has found very little favor among television engineers.

We have not mentioned very much about the lenses which are used in mechanical scanning systems. It is obvious that in the lens disc, only simple crown glass lenses canb be used. Lenses in the optical systems of other types of scanners are usually designed only from the standpoint of maintaining the spherical aberration at a minimum. The light is usually arranged to fall on the lenses at such small angles from the optical axis that the other distortions become relatively unimportant. Very often achromatic lenses are used in the television scanning system, but oddly enough, not so much to correct for chromatism but simply because these lenses are usually better corrected for spherical aberration than the ordinary type. Wherever possible, of course, the various lenses must be cemented together or cemented to parts of the system so that the reflection losses can be kept at a minimum. This particularly applies to the light valve. Very often Kerr cells are used for the light valve. When they are employed the lenses on either side of the cell can be cemented directly to the container and thus eliminate some reflection losses. The lenses must be arranged to properly focus an image of the source on the screen unless another method due to Traub is used. This consists of filling each lens completely with light and then focusing an image of the second last lens on the screen it self. In this way a maximum amount of light is sent to the screen. In other words each lens employed forms an image of the lens next before it on the lens which follows it, and thus each lens is a field lens with respect to the lens on either side of it. This insures that no light is lost due to divergence of the extra-axial rays. It is a well known law of optics that a lens which is filled with light from any source appears when viewed from the image of that source to be a bright object with a brightness equal to the source itself. Consequently, it is immaterial whether the final image appearing on the screen is an image of the source itself or one of the lenses following it. Several advantages, however, result from this practice. First if we wish to control the size of the image we can vary the aperture of a comparatively large lens instead of a small image so that the adjustments can be more easily made. Secondly, the source itself is seldom a regular point, More often it is the filament of an exciter lamp or Mazda, etc. Thus, if an image of the source is formed at the screen, the spot will be irregular and unsatisfactory, whereas if an image of the lens is formed a nice round evenly illuminated spot will result. It will be apparent that this device is only useful if the number of lenses can be kept comparatively low. Otherwise the losses due to absorption and reflection in the lenses would make the attendant inefficiency so great as to outweigh its advantages. In one commercial form of the Mihaly-Traub system the losses in the lens system are maintained as low as possible by eliminating some of the lenses by using concave ring mirrors. The mirrors are used to form a reduced image of the lenses preceding them and this image is projected on the screen by the final projection lens between the mirrors and the slow drum.

Extensive research is now going on in an attempt to raise the efficiency of mechanical scanning systems. As we have seen from the foregoing, the Mihaly-Traub system in conjunction with crossed drums seems to be the most efficient to date. There are several methods by which the light efficiency may be increased without increasing the brightness of the source itself. When the most efficient system has been determined it is evident that only increasing the size of the whole apparatus can increase the illumination of the screen. This is a fundamental of the design of television scanning systems. The system must be designed just as efficiently as possible and then the size increased until the illumination becomes adequate. Very often in the past this method has led to the design of machines which were totally undesirable for the home, yet were suitable for theater use, etc. It is plain, however, that once the efficiency has reached a certain point, only increase in brute size of the apparatus can increase the illumination. One possible line of advance is in the development of new light sources having greater intrinsic brilliancy and greater electrical efficiency. Light sources have been developed which can give a brilliancy of 1,000,000 candle power per square cm. but at present they have a life of only a few hours. Furthermore, such a source is so unwieldy as to be unsuitable except for theaters. Similarly, arc lights are considered unsuitable except for theater use. For this reason incandescent electric lamps are usually used for home receiver purposes. A new type of source, however, was announced by the Scophony Company some short time ago which is extremely efficient and yet economical to run. This takes the form of a special form of high pressure mercury arc discharge lamp.

Light Losses

The greatest losses encountered in the optical system of a mechanical television receiver occurs in the light valve. At least two polarizers must be used, one on either side of the Kerr cell, and if they are of the more conventional type such as Thompson or Nicol prisms a large amount of light is lost by absorption through the prisms and also by reflection and absorption occuring in the lenses which are required to collimate (render parallel) the light which passes through them. Nitro benzene is usually used in the cell to effect the rotation of the plane of polarization. The absorption of light by the substance is extremely high. A column of nitro-benzene 4 cms. in length (about the usual length) absorbs 24% of all the light which passes through it. Due to the high capacity and the consequent high frequency losses which occur in multiplate Kerr cells, the simple type is usually preferred. The spacing between the electrodes is usually less than 1 mm., and as the width is usually not very great, the amount of light which can be passed through is quite small. The combination of these various losses is so serious that they are sometimes reckoned to consume 80% of the light which is incident upon the first polarizer. Thus, at the very outset the amount of light available is seriously depleted. It seems likely that if wide aperture polarizers such as sheet polaroid were used, the efficiency would be greatly increased. The polarizers that have been used in the past may be compared to thin bottle necks through which all the light which is later to be used to illuminate the screen must be passed. It also seems possible that notwithstanding the serious electrical losses of the multiplate type of cell, the latter could be used with polaroid so that increased optical efficiency would more than outweigh the electrical disadvantages. Even if a multiplate cell were not used, polaroid would enable much more light to pass through the cell if the plates were of V variety because of the greater entrance angle that could be used.

Probably the greatest single advance in the realm of light valves has been made by Jeffree in his utilization of the Debye-Sears effect, wherein supersonic sound waves passing through a liquid medium are used to modulate the light. This valve not only has the advantages of cheapness, good modulation characteristics, and contrast, but also enables an almost revolutionary method to be used. The device allows three advantages; first, it allows much more light to pass through thanhitherto had been possible; secondly, it allows the formation of an image of the source near the plane of the scanning mirror with a consequent increase in light transmission; thirdly, it allows a whole line of the picture to be projected onto the screen at one time. These, however, are just optical advantages. On the electrical side of the instrument we have the advantages of good frequency response, only a small amount of power required for modulation purposes, and extreme reliability.

Thus it will be seen that the greatest advance that can be expected in the realm of mechanical scanning systems will not lie in the field of the scanners themselves, but rather in their associated light valves. At the present time the Scophony light valve which uses the Debye-Sears effect seems to be the most promising solution to the light valve problems. However, it seems certain that further development of new types of Kerr cells will occur. When it is remembered that tremendous advances have been made in that direction in the past few years, it seems very likely that a Kerr cell having many times the light efficiency of the ones in use at the present time will be developed in the near future.

CHAPTER IV

ELECTRONIC TELEVISION CAMERAS

The disadvantages of mechanical scanning are due to:

1. The large physical size of the apparatus required.

2. The small amount of light that is picked up by the scanning aperture.

3. The mechanical difficulties inherent in the system itself.

While these three items are listed separately, they are closely related. The reason for the large physical size, for example, is due to the desire to obtain as much light through the scanning aperture as possible. Naturally, a large sized hole is desirable. But if we use a large aperture, then we must increase the area of the scanning disc if a reasonable number of holes are to be accommodated. This brings us back to the physical size of the equipment again. As an illustrative example, suppose that it were desired to obtain the same number of lines that is used today by electronic means, namely 525. In one second, 15,750 lines are scanned. If the projected picture width at the scanning apertures is two inches, the scanning apertures must move 31,500 inches in one second. Assuming the scanning disc has a diameter of 4 feet (which represents a considerable area) the necessary scanning speed can be obtained only by 12,540 revolutions per minute. Anything 4 feet in diameter, revolving at this relatively high speed would have to be almost perfectly balanced in order not to vibrate. Vibration would displace the scanning apertures and cause the lines to move up and down.

A smaller disc would require smaller aperture openings. The difficulty here is the limitation on the amount of light that can pass through the opening to reach the photoelectric cell located behind the scanning disc. Higher light intensities would overcome the light problem, but here we run into discomfort for the actors, due to the heat generated and the blinding light. When all these factors are considered, electronic scanning is far superior. Hence its acceptance.

Electronically, three types of cameras are in current use. These are the familiar iconoscope, the image dissector and the new image orthicon. Each possesses properties which make it best suited for a particular purpose. Thus, under present conditions, the iconoscope is used chiefly for the indoor television studio; the image orthicon for outdoor events and scenes that must be taken under poor lighting conditions; finally, the image dissector is widely used for scanning films. Why these limitations exist will be explained presently.

THE ICONOSCOPE

The "Iconoscope" is the name given by Dr. Vladimir Zworykin to his television pick-up tube. The word itself is derived from the Greek word "ikon" meaning "image" and the ending "scope" meaning "instrument". Actually "iconoscope" means "image viewer". This device shares honors with the Farnsworth "image disector" tube as being the only successful electronic pick-up ever devised for television purposes. Today, it is practically a commercial article, but its history of over fifteen years of research is a tribute to the never tiring patience and skill of the modern scientists.

Before the Iconoscope, there were two general methods of televising an image, the one most widely used scanned the image with a spot of light, and picked up the resulting diffused light from the object being televised. The other type widely attributed to Jenkins consisted of placing the photo-electric cell behind the scanning disc, and generally speaking was unsuccessful due to the small amount of light which was able to effect the pick-up device. As the television art progressed, more and more detail was demanded in the televised picture, and the time, therefore, that the actual light fell on the photo-electric cell while one element was scanned became less and less, and consequently, the output level of the pick-up device decreased in proportion.

Then, came the Iconoscope. In this device, instead of the light from each element falling upon the pick-up device just a very short time corresponding to the time it takes to scan that element light is falling on the sensitive image plate of the tube all the time. This is the memory feature of the "Iconoscope" which has been so widely publicized, and it is this feature which makes the Iconoscope the most sensitive television pick-up ever devised.

The construction of an Iconoscope is quite complex. Essentially an electron gun is mounted in such a manner that a beam of electrons sweeps over a retina like plate called the mosaic plate. This plate consists of an insulating substance such as mica which is backed by a plate of nickel or other conducting material, and the other surface of which is covered by thousands of tiny photo-electric globules. An optical image is also focused upon the mosaic plate and the electron beam is deflected so that it scans this in a desired manner.

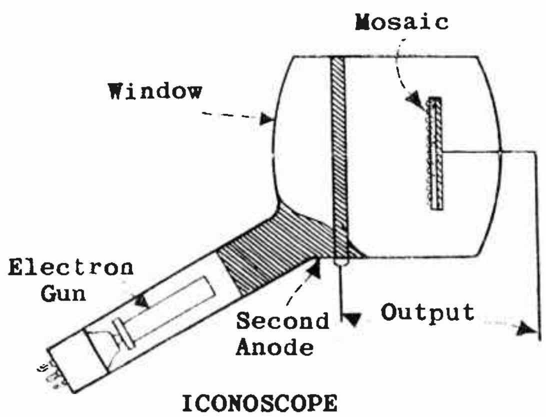


Figure 1.

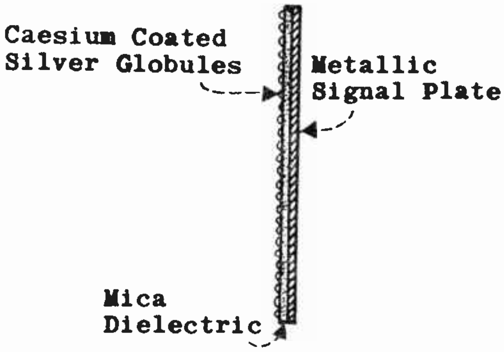
The arrangement of the electrodes within an Iconoscope is shown in Fig. 1. The output of the tube is taken from the plate that backs the mosaic and the conducting coating within the tube itself. The latter also acts as a second anode of the electron gun which is used to scan the image.

When the image falls upon the photo-electric surface of the image plate, each portion of the image, depending upon the intensity of the light which corresponds to that portion, causes photo-electrons to be emitted. The number of photo-electrons emitted is proportional to the amount of light falling upon the surface. As the surface is divided up into a tremendous number of small elements, each of which is insulated from the other and the photo-electrons which are emitted are drawn to the second anode coating, the charge residing upon each element remains there and can not neutralize itself. If the image light is allowed to fall upon the plate over a period of time, the charges will build up correspondingly to this image and will grow larger depending upon the time the plate is exposed. That is, each element of the surface sums up the intensity of the light which falls upon it over the period of time that it is exposed. Theoretically, therefore, the Iconoscope should be as many times more sensitive than the ordinary pick-up as there are elements in the picture. Thus, if a picture was scanned by a system using 400 lines, an Iconoscope should have a response equal to 400 x 400 or 160,000 times as great.

In actual practice, however, this increase in sensitivity is not so great. Usually only ten percent of this theoretical gain is realized, but the output is still many thousand times greater than the older system.

Theory of Operation of the Iconoscope

The mosaic, as mentioned previously consists of tiny silver globules which are insulated from one another. (See Fig. 2.) On the surface of the silver globules is deposited a thin film of Caesium which acts as the photo-electric element. When a beam of electrons from the electron gun of the Iconoscope strikes the mosaic surface, the high velocity electrons cause secondary emission electrons to be driven off the mosaic at the point at which the beam is striking. As a matter of fact, more electrons leave this point than arrive so that the point in question is driven up to a positive potential because of a deficiency of electrons. For the material used in the Iconoscope, the potential under the electron beam is driven up to approximately + 3 volts. This value is known as the EQUILIBRIUM POTENTIAL and is the same for any point on the mosaic that happens to be under the electron beam. Some of the secondary electrons which are driven from the spot under bombardment redistribute themselves over the surface of the mosaic. This redistribution of negative electrons, which is more or less uniform over the portion of the mosaic not under bombardment, causes the mosaic to assume a negative potential of approximately —1 1/2 volts. The secondary electrons that reach the collector or second anode constitutes the signal current.



CROSS-SECTION OF MOSAIC

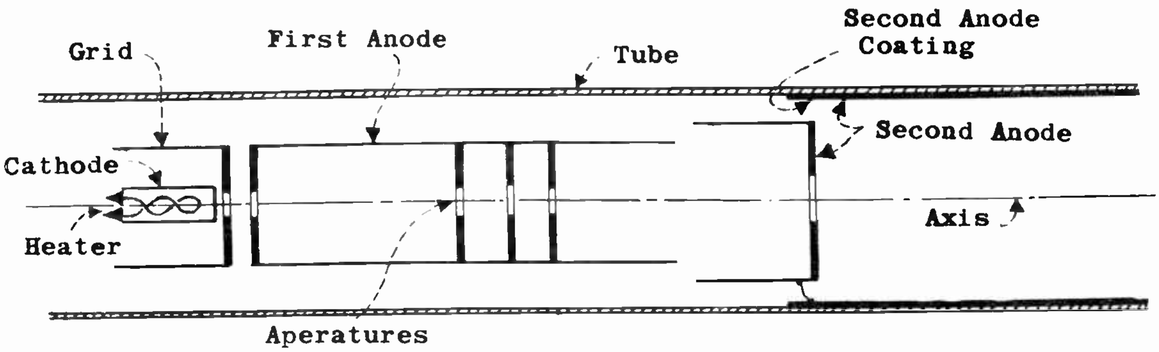
Figure 2.

When an image is focused on the mosaic, some portions of the mosaic will receive more illumination than others. Because of the photo-electric property of the mosaic, the illuminated elements are at a more positive potential than the elements that are not illuminated. Inasmuch as the element of the mosaic under bombardment is driven to the equilibrium potential regardless of the original potential of that element, the change in potential of an element during bombardment will be different for elements having different illumination. Consequently the secondary emission from an element that is not illuminated. The secondary emission electrons that reach the second anode constitute the picture signal. Inasmuch as the signal current thus received is dependent on the image on the mosaic, the signals can be used to reproduce a picture at the receiving end when properly amplified. As the electron beam is made to scan the image progressively a series of voltage fluctuations are obtained in the output circuit which are proportional to the light which falls upon the image plate.

CONSTRUCTION:--The construction of the mosaic plate consists, as stated above, of a very thin insulating plate backed by a nickel plate on whose surface is deposited photo-electrically sensitive globules. In actual practice, the nickel plate is often enamelled. In other cases, a very thin mica sheet which has been carefully selected and examined to make sure that it has no small imperfections is used. In order to form the photo-electric element surface, the insulating surface is covered with silver globules, then this assembly is placed, together with the other elements, within the tube and the tube is highly evacuated. The elements are thoroughly outgassed by using a high-frequency bombarder and when the silver becomes heated, oxygen gas is allowed to flow into the tube and a chemical reaction takes place between the gas and the silver particles. The reaction is carefully controlled in order to produce the right chemical compound and is usually determined by the color of the plate (a yellowish brown). Then the tube is again pumped out making sure to remove the last trace of oxygen. Caesium metal vapor is now admitted into the tube, while the glass walls of the tube are kept quite warm in order that the metal will deposit only on the image plate. Only a small quantity of Caesium is used, because a layer of the metal just a few atoms thick is preferred.

The mosaic must be made with extreme care in order that (a) the electrical insulation between the various photo-electric elements will be as complete as possible; (b) that the silver oxide formed may be the correct one for this purpose; (c) that the layer of Caesium metal may be deposited only on the silver oxide globules; (d) that the amount of Caesium deposited should be the proper one.

It may be well to mention here that the photo-electric globules are very much smaller than the scanning spot.



ICONOSCOPE GUN

Figure 3.

The electron gun used for scanning the image of the Iconoscope is built quite similarly to the gun used in the conventional cathode-ray tube. See Fig. 3. The gun used must be very carefully designed and constructed. In order to dissect an image into say 400 lines and using a mosaic plate four inches in height, the beam spot should be approximately .005 inches in diameter. To design a gun capable of producing such a spot is quite a difficult problem. The final anode is a coating composed of silver or Aquadag which is deposited upon the bulb's inner surface, which is usually charged 1,000 volts positive with respect to the cathode. This anode, incidentally, also forms the collector plate for the electrons emitted by the mosaic.

The deflection of electron beam for scanning the mosaic is accomplished by magnetic fields. The deflection coils are mounted on a yoke which fits over the neck of the Iconoscope. Deflection can also be accomplished by electrostatic fields.

The deflections must, of course, as in the case of any system of television scanning, be linear. That is, the degree of deflection must vary directly with time.

In order to produce this type of deflection, saw-tooth wave generators are used. Usually these are thyratron tubes in a condenser circuit. The action of the thyratron and the process of linear scanning are fully explained in advanced assignments.

You will notice that in the Iconoscope, the electron gun is tilted at an angle to the surface of the mosaic cathode. (See Fig. 1.) This angle is 30 degrees. Naturally, it is a longer distance from the electron gun to the top of the cathode than it is to the bottom of the cathode, and consequently, a so-called keystone distortion is introduced; that is, the electron beam tends to scan a longer line at the top of the image than at the bottom of the image, and the image becomes no longer square as far as the transmission is concerned.

To compensate for this distortion, a voltage is applied to the horizontal sweep circuit from the vertical sweep circuit so that when the beam is at the top of the cathode, it tends to sweep a much shorter line than usual. When it is at the bottom of the image, it tends to sweep a much longer line than usual. The effect of this is that when this voltage is of the correct value and is properly timed the keystone distortion is completely compensated for. That is, the image that is actually scanned by the electron becomes square. The circuits used to compensate for keystone distortion are fully explained in advanced assignments.

The Iconoscope is practically a self contained pick up unit, and so, very compact portable cameras have been designed around it. These also usually contain two amplifier stages connected by means of a long cable to the main amplifier and the deflecting units. However, sometimes experimentally an electron multiplier is used as the pre-amplifier with the Iconoscope.

The sensitivity of the Iconoscope is comparable to that of a photographic film operating at the speed of a motion picture camera which uses the same optical system. Its color response is such that it is sensitive to infra-red and ultra-violet light as well as light which is visible to the eye.

Processing of the Mosaic

Methods for the deposition of the photo-cathode, or mosaic, are continually being improved, and several refinements have only recently been inaugurated.

A serious difficulty which sometimes arose was that of specular reflection from the uncoated mica of the mosaic. That is, the uncoated inter-globular spaces would reflect light from the image back to the window from which it was then reflected to another element of the mosaic. This condition is illustrated in Fig. 4. The undesired effect of this is eliminated by sandblasting the mica so as to convert the specular reflection into a diffuse one which is not troublesome.

A thin layer of cryolite (a compound of sodium, aluminum, and fluorine, Na_3AlF_6) is then flashed upon the mica. This expedient tends to prevent leakage between the elements of the mosaic in the finished tube, and, therefore, allows a greater tolerance in the amount of sensitizing metal which may be employed without shorting the globules.

Exact methods of preparing the photo-sensitive surface vary among experimenters. The first stage in the preparation of the mosaic is the means of obtaining a uniformly thin film of silver globules on the mica. This is usually done by dusting very finely divided silver oxide on the cryolite-coated surface. The sheet is now heated, causing reduction of the silver oxide to silver in the form of discrete globules. Following this, successive layers of the oxide are dusted on the surface (each layer being reduced in turn) until the silver globules cover about two fifths of the mosaic, while three fifths of the area is taken up by the inter-globular spaces.

The back of the mica is coated with a film of platinum which acts as the signal plate. Another piece of platinum coated mica is mounted so that the two platinum surfaces are in contact. An external connection is made to the signal plate thus formed.

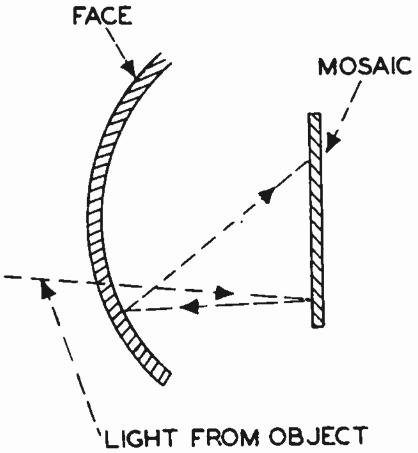


Figure 4.

The mosaic is now sealed into the envelope, and the entire structure is evacuated and baked at about 400° C. The tube must now be allowed to cool thoroughly.

The silver globules are now oxidized by passing a discharge through oxygen at a pressure of .001 mm. to .1 mm. The discharge can be effected with the aid of a high frequency coil placed over the tube. When the oxidization process begins, a change in color of the surface will be noted, and for maximum sensitivity a dark yellow color is sought. At this stage, if the oxide is not properly formed, the film can be again reduced to silver, by re-evacuating the tube, and baking until the silver oxide is reduced. Oxygen is again admitted and the discharge process is repeated until a satisfactory silver oxide layer is formed. After this, the tube is baked at a medium temperature and excess oxygen is evacuated.

The mosaic is now ready to be coated with caesium, which is in a getter capsule that has been placed, either in a side tube to be subsequently sealed off the main tube, or it has been attached to some convenient electrode within the main tube. The caesium is usually in the form of a salt such as caesium chloride or caesium dichromate, and is intimately mixed with powdered calcium or tantulum. The caesium is now evaporated, during which process the calcium or tantulum combines with the chloride or dichromate of the original salt. The caesium vapor distills upon the mosaic surface which assumes a darker brown tone as the caesium reacts with the oxygen. The caesium is evaporated until the photo-electric sensitivity is at its maximum, which is taken to be when the caesium layer is monomolecular in thickness. During this sensitizing period the mosaic is kept illuminated and the photo-electric output is measured by a vacuum-tube voltmeter, until a maximum yield is indicated. If the sensitivity does not come up to expectations, the caesium may be removed from the mosaic by raising the oven temperature. At the same time the silver oxide is again reduced to silver and the process begins anew with the oxygen discharge. The fresh supply of caesium may be obtained by further heating the caesium capsule.

The above procedure results in the heretofore standard $AgCs_2OCs$ surface, the sensitivity of which varies between 3 and 10 microamperes per lumen. A recent innovation, however, consists of evaporating an extremely thin layer of silver on the caesium surface prepared as above, resulting in a sensitivity ranging between 9 and 15 microamperes per lumen. Higher values may be obtained but when these occur the infra-red response is generally too great. However, if this silver sensitization is carefully controlled with regard to evaporation and subsequent baking, the white-light sensitivity may range between 15 to 30 microamperes per lumen, while the infra-red response will be held down to the correct value. An excess of infra-red sensitivity causes a graying of black values.

In practice, different methods of this final silver sensitization result in two types of iconoscopes, known as the "movie pickup" and "direct pickup" iconoscopes. In the former, the silver evaporator is surrounded by a shield which allows silver to be deposited only on the mosaic; while in the "direct" type, the evaporator is designed to deposit silver on the walls of the envelope as well as on the mosaic. In the "movie" type, the silver must be deposited only on the mosaic, as a spurious signal is caused by the intermittent and rapidly changing illumination encountered in conventional movie projection when the walls of the tube are photosensitive. In the studio, however, where the illumination is continuous, the photosensitivity of the envelope walls can be used to advantage. A so-called "bias" light is placed so as to illuminate the walls, but not the mosaic. A considerable increase in sensitivity and output is obtained, due to the fact that photo-emission from the walls produces a more advantageous field for the collection at the second anode of the photo-electrons emitted by the mosaic. By using this effect the signal output may actually approach double its value without the bias light. Moreover, lower beam currents may be employed for a given output. Thus, the output obtained with a .1 microampere beam current with a bias light is actually greater than that obtained with a .25 microampere beam current without a bias light.

The current output for various values of illumination is probably the most important characteristic of the iconoscope. In Fig. 5 is a diagram of the apparatus frequently used for this measurement. Light is projected upon the mosaic through a slit in front of a lamp operated at 2870 degrees Kelvin. The intensity of this light is controlled by a variable (iris) diaphram, for every setting of which the illumination falling on the mosaic is known in lumens per square centimeter.

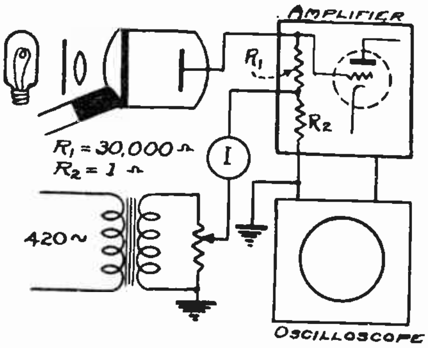


Figure 5.

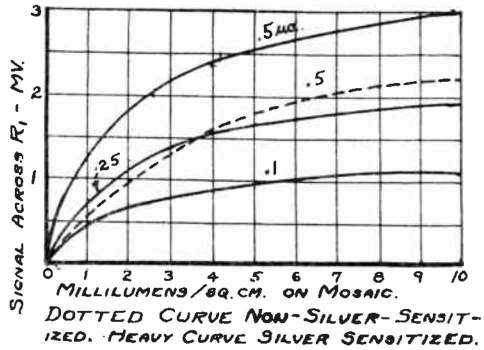


Figure 6.

The current from the iconoscope passes through a resistor (R_1) of 30,000 ohms, and the voltage thus appearing across this resistor is amplified by a regular video frequency amplifier. The amplifier is calibrated by having a known current of 420 cycles pass through resistor R_2. The output of the system is applied to an oscilloscope. If the system has been properly calibrated, the voltage across R_1 can be determined by reading the height of the signal on the oscilloscope tube. Fig. 6 shows graphically the results arrived at by this method for different values of beam current in a silver-sensitized tube. The dotted curve shows the output from a non-silver sensitized mosaic with a beam current of .5 microampere. Note how it compares with the output of a sensitized mosaic using a .25 microampere beam current.

The sensitivity in microamperes per lumen may be determined by allowing a known intensity of light to fall upon the mosaic for a short interval, about 1/100 second. For longer periods of time the mosaic may charge up, resulting in erroneous measurements. The calibration is made by means of a phototube whose sensitivity has been previously calibrated.

Another characteristic of the iconoscope is the ratio of secondary emission from the mosaic. The secondary emission ratio is less in silver-sensitized tubes than it is in non-sensitized ones. In one particular tube under test, the secondary-emission ratio increased with increasing beam potential up to about 400 volts, and thereafter became an inverse function of the beam potential. This was true of both sensitized and non-sensitized mosaics. It is interesting to note that although the secondary emission ratio finally decreased with higher beam voltages, the signal output varied directly with the beam potential. We may conclude, therefor, that the effect of small changes in the secondary emission ratio on the signal output is small for the values of secondary emission encountered in these tubes.

The spectral response of the iconoscope is the next consideration. This may be determined by means of a special color chart (used in conjunction with a kinescope) which has four color-graduated columns. The first column contains progressive shades of red, the next yellow, the third green, and the fourth blue. In addition, there is another column with various shades of gray, from white to black. A certain arbitrary number is assigned to each shade in each of the columns. Since color values are not indicated by the kinescope, the relative response is indicated by the intensity of each shade as reproduced on the kinescope screen. Now, if the mosaic has the same spectral response as the eye, the intensity for a given shade, corresponding to the assigned number, say 100, in each of the colored columns, will be the same as the intensity of the shade of gray corresponding to 100 in the black-through-white column. As previously mentioned, the amount and type of silver-sensitization exerts a considerable influence over the color response.

The last consideration is that of the resolution. Without silver sensitization, tubes not having satisfactory resolution could be improved only by baking, if at all. With silver-sensitized tubes, it has been found that the resolution improves during the sensitizing process. If the resolution is not sufficient after this sensitization and baking, further evaporation of a small amount of silver generally gives satisfactory results. The final resolution can be made at least as good as for non-sensitized tubes, and often better. The method for measuring resolution will be discussed later.

Theory of the Iconoscope

A simplified explanation of the operation of the iconoscope was given in the first part of this lesson to acquaint the reader with the tube. Actually, however, it is found that a full explanation involves a more extensive analysis and this is presented below. The iconoscope may essentially be considered as a mosaic made up of a great many individual photocells, all connected to a common signal plate by capacity, and scanned by an electron beam.

Each globule emits photoelectrons of a number proportional to the amount of light falling upon it from the image. The resulting loss of electrons leaves each element at a positive potential proportional to the number of electrons released, so that the mosaic tends to go positive at a rate proportional to the light falling on it. As the scanning beams strike each element in turn, the charge is released and the elementsis driven to equilibrium. Because of the capacity existing between the mosaic and signal plate, the changes in charge of the elements will result in current pulses in the signal lead, whose magnitude will be proportional to the light intensity on the scanned elements.

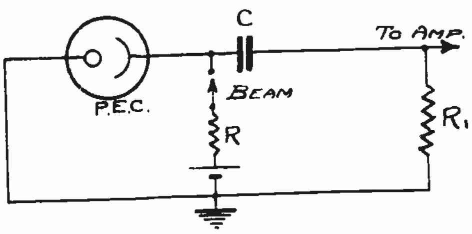


Figure 7.

The simplest analogous equivalent circuit for a single element is shown in Fig. 7. The scanning beam is represented by the switch and series resistance R. The switch may be considered to be open except when the beam is actually on the element. When the beam moves off the element, the photo-emission from it starts to charge condenser C at a rate proportional to the illumination of the element. In the next scanning cycle, the beam again strikes the element, closing the switch and discharging the element. During this discharging period the entire charge accumulated during the time the beam was not on the element must now flow through the input resistor R, producing a voltage which is applied to the amplifier. To effect this action, it is evident that the time constant of the discharging circuit must be small enough to allow a full discharge during the time the beam is on the element. Consequently, $(R_1 + R) \times C$ must be less than the time the beam is on the element, a condition not difficult to fulfill in practice.

While the above concept is satisfactory for some purposes, if carried too far, it may lead to erroneous conclusions. The beam itself cannot be called a commutator, or contactor, because its effective resistance is substantially infinite. With most electron guns in high vacuum tubes the potential of the target (mosaic) can be changed by a thousand volts without altering the beam current by so much as a fraction of a microampere. A conducting commutator could not behave in this way. It has been estimated that there are some 65 million globules on the mosaic, of which about 300 are under the beam at any instant. Hence, the idea of individual elements should be used with reservation, and the mosaic should be regarded from the standpoints of the potential distribution over its surface, and the redistribution of secondary electrons emitted by the mosaic under bombardment.

The average potential of the mosaic (with no incident light) while being scanned is generally between 0 and 1 volt negative with respect to the electrode which collects the electrons leaving the mosaic, i.e., the collector. The potential, however, is not uniform over the surface of the mosaic. Elements directly under the beam are about 3 volts positive with respect to the collector. Those elements which have been previously bombarded are less positive, until a point one-quarter to one-third of the vertical distance along the mosaic from the point being bombarded the potential is about - 1.5 volts, as is the rest of the mosaic. An approximate representation of the potential distribution is shown in Fig. 8, the graph of which was obtained by cathode ray oscillograph measurements.

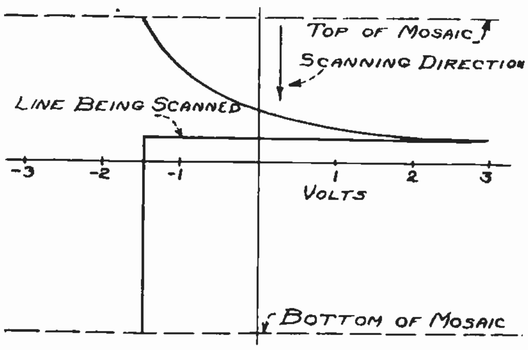


Figure 8.

Further elaboration on the mosaic potential leads us to consider the following. When a caesiated silver surface is bombarded by a 1,000 volt electron beam, a secondary emission of 7 or more times the primary bombarding current can be collected. However, since the mosaic elements are insulated, they will assume a state such that the secondary emission current equals the initial current. This will occur when the mosaic has acquired a certain potential, known as the equilibrium potential, the value of which for caesiated silver surfaces is about 3 volts positive with respect to the collector. When the equilibrium potential for a given type of surface is reached, the average secondary current escaping to the collector equals the bombarding current. Until the equilibrium potential is reached the secondary emission ratio will be greater than unity.

The secondary emission from the mosaic may be divided into three parts, that going to the collector, another returning to its parent photo-element, and the third being redistributed over the entire mosaic. This last group returns as a more or less uniform shower of electrons of low velocity, their initial velocity not being sufficiently high to permit them to leave the mosaic entirely. Only when the mosaic is relatively quite negative do all the secondary electrons reach the collector. Thus, the potential of a point (element of the mosaic) struck by the electron beam determines how much secondary emission will escape, and how much will return near or far from the point of origin. Hence, it is deduced that the part of the secondary emission reaching the collector varies according to the mosaic potential established by photo emission, which in turn, depends upon the incident light intensity.

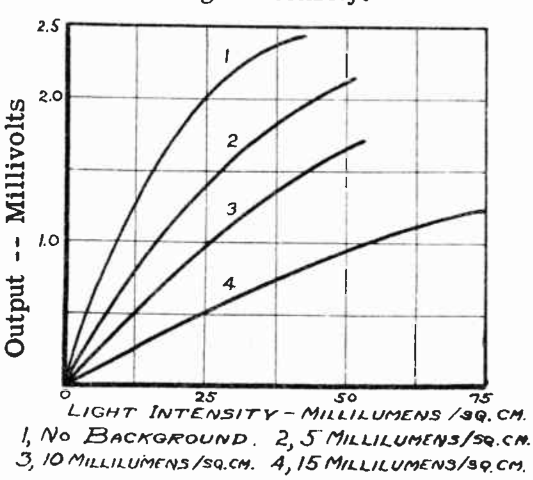


Figure 9.

The photo-electric emission from the mosaic is not very efficient, and becomes less so as the illumination is increased. This is graphically depicted in Fig. 9. Curve 1 represents the output from a small illuminated area with the remainder in darkness. With curves 2, 3, and 4, the mosaic has a uniform background of light. The response is not linear but decreases as the illumination is increased until it reaches a saturation value. The decrease in sensitivity at higher illuminations may be due to the reduction in the secondary emission ratio concurrent with the mosaic's reaching the equilibrium potential. However, the decrease in response is not entirely disadvantageous since it permits the transmission of a wider range of contrast.

The electrons falling back on the surface of the mosaic act to some extent as a high resistance, short-circuiting the elements, since an element which is more positive than those about it tends to receive a greater share of these electrons. Ordinarily the resistance is sufficiently high so as not to produce a very serious loss in efficiency, but under high illumination where considerable difference in charge between nearby elements may arise, this shunting resistance may become relatively low with a resultant fairly large loss of signal.

However, the redistribution of electrons is responsible for the generation of a spurious signal, which appears as an irregular shading over the picture even when the mosaic is not illuminated. This is caused by the variation in instantaneous secondary emission excaping from the mosaic. As previously noted, the average secondary electrons from the mosaic must be unity. However, a certain fraction of the secondary electrons from a point under bombardment returns to other parts of the mosaic, and consequently the instantaneous current leaving the mosaic may vary from point to point. The variation results from the non-uniformity of potential and space charge over the mosaic. The spurious signal may be considered as divided into two parts. The first is the effect due to the signal stored by the mosaic, while the second is an instantaneous effect depending upon the variation of potential of the mosaic. The instantaneous component can be demonstrated easily by substituting a metal plate for the mosaic. When this plate is scanned in the usual way and being maintained at a potential close to that of the second anode, a spurious signal results which is very similar to that from the mosaic, although the mechanisms of their generation are not exactly the same. If the potential of the plate is made negative or positive with respect to the collector, the secondary emission will be saturated, or suppressed, and the signal will disappear. In practice, the introduction of a compensating signal is used to offset the spurious signal. This is generally known as a "shading control" and will be mentioned later.

As previously explained, there is a line across the mosaic which is 3 volts positive with respect to the collector, while just ahead of the beam the potential is about 1.5 volts negative. (See Fig. 8.) There is, therefore, just ahead of the scanning beam, a row of elements which have a strong field aiding the leaving photo-electrons. This field greatly increases the sensitivity along this line, resulting in what is termed line sensitivity, an effect which may be demonstrated in the following manner. The image from a continuously run moving picture film is projected upon the mosaic, using the same speed for film and television systems. The image from the film is caused to move opposite to the vertical direction of scanning. Under these conditions it is found that the iconoscope transmits a clear image of two frames of the film, although to the eye there appears to be only a blur of light on the mosaic. At low or normal light intensities, the greater part of the signal comes from surface sensitivity, but under high illumination a considerable portion of the signal may come from line sensitivity,

It can be shown that of the total charge released by an element when struck by the beam only about one-fourth will reach the collector, the remainder returning to the mosaic, so that only about twenty-five percent of the stored charge is available for producing the picture signal. Considering the various factors tending to reduce the output of the iconoscope, the overall efficiency of conversion is on the order of 10%. In other words, the signal output is only a small fraction of the elements, and the assumption that the entire photo-current is stored by the mosaic. As stated before, the efficiency decreases at higher light intensities. Since an earlier assignment described limitations imposed by noise, we will here only add some quantitive data. Tests have brought out that if the root-mean-square noise level is equal to 30% of the picture signal level, the picture is still recognizable, but the resolution suffers, and the picture is tiring to watch. A good picture can be obtained if the ratio of signal-to-noise is ten to one, but the noise is still noticeable. A picture may be considered excellent from this standpoint when the noise is reduced to three percent of the picture.

The Farnsworth Image Dissector Tube

The type of tube shown in Fig. 10 was invented by Philo T. Farnsworth and shares with the Iconoscope the honor of being the most successful type of electrical television pick-up. It is widely used in television transmitter installations, among them being the Baird installation at the Alexandra Palace in London, England.

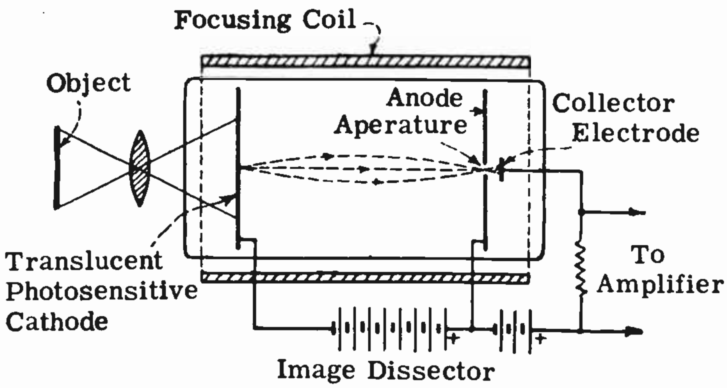


Figure 10.

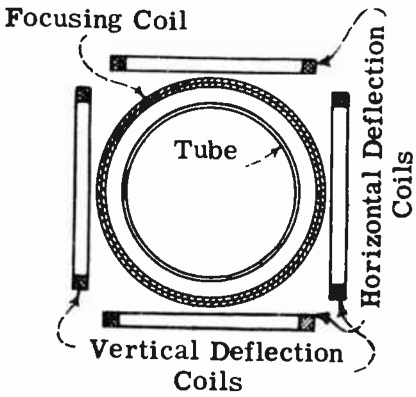


Figure 11.

The Farnsworth tube does not have the "memory" feature of the Iconoscope. The electrons emitted from this photo cathode are returning continuously to it via the anode, and thus no charge corresponding to the amount of light and the time that the light falls upon the cathode is built up as it is in the Iconoscope.

Basically, the Farnsworth image dissector tube consists of a translucent photo-sensitive cathode located at one end of the large tube. (See Fig. 10.) This surface is mosaic in structure and is a Caesium or silver surface. At the other end of this large vessel is located the anode, which consists of a large disc the size of the tube with a small aperture located in its center about fifteen thousandths of an inch square. The inside of the cylindrical tube at the ends of which are located the cathode and anode, as explained above, is coated with nickel to provide a return path for the electrons. A magnetic field, focusing coil, is placed about the tube so that the whole path of travel of the electron from cathode to anode is within this magnetic field. In order to provide this field, a large cylindrical coil which just fits over the tube and extends from the one end to the other is connected to a source of current.

When an image is focused upon the photosensitive cathode of the tube, electrons are emitted from each element of that cathode, the number being proportional to the amount of light in that portion of the image. These electrons are attracted by the highly charged anode. Ordinarily, if several streams of electrons such as those proceeding from the cathode to the anode of this tube were to travel such a distance in free space, they would mutually repel one another and also they would tend to assume an equal distribution throughout the cross section of the electron image. If this was to occur, the electron image would be diffused into merely a large stream of electrons. However, as the path of the electrons is completely submerged in a magnetic field and the magnetic lines of force then extend in straight lines from a cathode to the anode, the electrons also tend to travel in straight lines. This is due to the tendency of the electron to follow a magnetic line of force. This action is more fully explained in the assignment on electron optics.

Behind the aperture in the center of the anode is located some means of picking up the electrons which pass through it, as shown by the collector electrode of Fig. 10. In the older type of tube, there was simply a positively charged plate which was connected to the preamplifier of the pick-up. In the later tubes, however, Farnsworth built an electron multiplier of his own design, in which the smaller number of electrons falling through the aperture is considerably increased before being impressed upon the amplifier. This electron multiplier is of the Multipactor type.

If the image is focused on the photo sensitive cathode of the tube as described before, the electrons will travel down the length of the tube to the anode, and the electrons which correspond in numbers to the intensity of the light of the center of the optical image will pass through the aperture and be amplified. Therefore, a signal will exist in the output of the amplifier associated with the apparatus which corresponds to this portion of the image. In order that the whole picture may be transmitted, it must be scanned progressively as in any other system. In order to do this, flat coils are placed about the tube at right angles to one another as shown in Fig. 11. These coils are connected to the horizontal and vertical sweep circuits which are arranged to produce the desired number of lines, etc. When these varying fields act upon the electron image within the tube, they serve to move the whole image back and forth, up and down, so that a different portion of the electron image passes through the aperture and is amplified. Therefore, signals will appear in the output of the amplifier which correspond to the optical image falling upon the photo-cathode.

You will see, now, why Farnsworth calls this device an "image dissector". The image is progressively broken down into its elements. It is dissected, and each of these elements is then amplified. The kinescope or the Farnsworth receiving device, the oscillite, acts to form these elements together again into the original optical image.

SCANNING

In most systems of scanning, the electron beam goes across the screen, then is blocked out and starts one line lower on the opposite side of the screen. That is, it always travels in the same direction. It does not scan to and fro.

The time that the electron beam is not on the screen is utilized for synchronizing purposes. Impulses from both the horizontal and the vertical sweep circuits of the Iconoscope or image dissector are fed into the amplifier circuit at dark times. At the receiver, a special circuit selects these impulses which are then fed to the reproducer sweep circuits and synchronism is thus maintained. More detailed explanations will be given on this subject in advanced assignments.

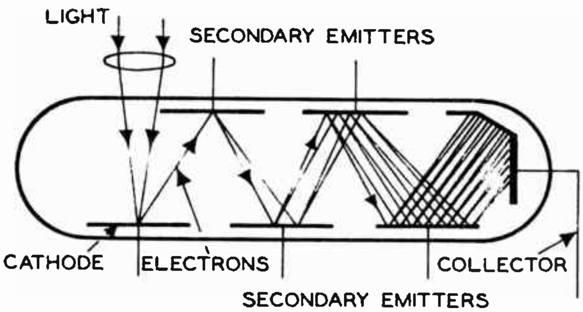
It is well to keep in mind the essential difference between the Iconoscope and the image dissector tube. In the Iconoscope, you will remember, the image is focused continuously upon its mosaic, and an electron charge image builds itself up on the mosaic which is many times greater than if the image had been exposed for only a short time. The image is then scanned by a beam of electrons. In the Farnsworth tube, no extra beam of electrons is used. An electron image corresponding to the optical image is moved to and fro over the aperture. All the elements of the electron image in the Farnsworth tube which are not passing through the aperture at any certain instant are producing no useful result at all. No charge is being summed up as in the case of the Iconoscope. Thus, on the face of it at least, the Iconoscope would seem to be superior. However, both types of pick-up have serious difficulties connected with their practical operation and at present in actual practice, it seems hard to decide whether one is superior to the other or not.

Television cameras have been improved by using a new type of preamplification known as:

Electron Multipliers

The electron-multiplier is an electronic amplifying device which has been developed in comparatively recent years. Its basic principle of operation differs radically from the conventional vacuum tube amplifier.

The amplification of a conventional system of vacuum tubes is limited largely by the noise level which is introduced by the grid resistor. The random fluctuations due to thermal agitation in this resistor limits the amount of amplification which can be obtained by the conventional type of device, irrespective of other considerations such as grid-cathode leakage resistor.



ZWORYKIN MULTIPLIER

Figure 12.

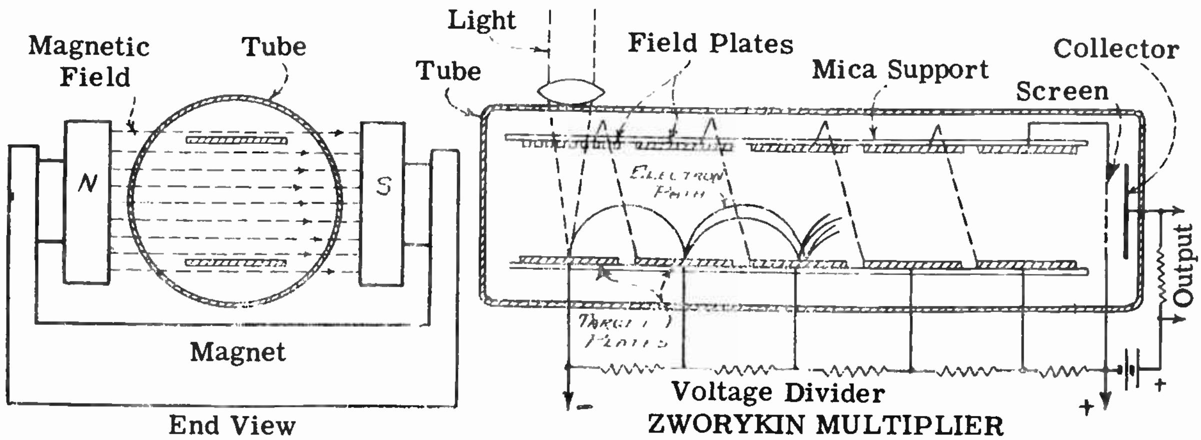
It was such limitations of the ordinary amplification system which led experimenters in different parts of the world to attempt to devise a radically new system of amplification. These efforts have been largely regarded only in the United States, where the electron multiplier tube of Zworykin and the Multipactor tube of Farnsworth have been developed to a practical point.

All types of electron multipliers utilize the principle that if a photo-electric surface is bombarded by high speed electrons, several secondary electrons will be emitted for each one striking the surface.

The two general types of secondary emission multipliers are the ones due to Zworykin and Farnsworth. In the former type, the multiplier is arranged in successive stages or in other words, primary electrons strike the first photo-electric surface, secondary electrons are emitted which are in turn accelerated and caused to bombard a second similar surface and so on. The second type of multiplier is one in which there are but two photo-electric surfaces surrounded by an oscillatory field. The period of oscillation of the field is equal to the time of flight of the electron from one surface to the other, and so the electrons strike one surface, liberate a greater number of secondary electrons, which owing to a reversal of the field, are accelerated toward the opposite surface and produce in turn new secondary electrons, and so on.

The most successful of these types of amplifying devices is the Zworykin type, and it has been built in three different forms. In the first form, the electrons are accelerated diagonally between the succession of plates which are placed in parallel planes as shown in Figure 12. In the second type, electron lenses are utilized to direct the secondary electrons from the one plate to the other. In the third type, a magnetic field is placed in such a manner that the emitted electrons describe cycloidal paths, and successively bombard plates placed in the same plane.

This type of multiplier employing a magnetic field is shown in Figure 13. The lower plates are target plates having good secondary emission properties while the upper plates are called the field plates. Voltages are applied to the plates by means of the voltage divider shown. Notice that each target plate is connected by means of a dotted line in the figure to a field plate that is one position to the left. The slanted dotted line between a field plate and a target plate indicates that the two plates are at the same positive potential. A magnet is located so that the lines of foce cut through the tube as shown in the end view of Figure 13. When a beam of light is focused on the first target plate at the left, photo-electrons will be emitted because of the photo-electric properties of the first plate. The first field plate which is a grid mesh and at a higher



ZWORYKIN MULTIPLIER

Figure 13.

positive potential than the light target will tend to attract the electrons. However, when the electrons travelling toward the first field plate pass through the magnetic lines of force, they will tend to be forced in a curved path toward the second target as shown in the Figure. On striking the second target, more secondary electrons are emitted and describe a curved path to the third target. This procedure is continued stage by stage until the final plate or collector is reached.

The surfaces suitable for the emission of secondary electrons are many, but the ones most generally used because of their high secondary electron yield is a Caesium on silver oxide surface. The secondary electrons sometimes numbering ten times the number of primary bombarding electrons.

Construction of the multipliers has not been very wide up to the present date due to the difficulty associated with the high vacuum technique necessary for this type of tube. The art of developing such sensitive photo-electric surfaces is also very new, and it is by no means a production proposition as yet.

Zworykin developed his electron multiplier largely for the purpose of amplifying delicate currents from his Iconoscope or television camera. For this purpose, it is invaluable, because of the low initial voltage available. Consequently, its extremely low noise level makes it about the only device which can be properly used for this purpose. The amplification which can be expected from such a device built into one single tube often exceeds ten million. It differs from the ordinary vacuum tube amplifier also in that an electron multiplier is essentially a current amplification rather than a voltage amplification device. The actual gain depends upon the number of stages and also upon a constant dependent upon the nature of the individual emitting surface and working voltage etc. Mathematically speaking, it is expressed as

$$G = s^n \tag{1}$$

where G is the gain, s is the constant of secondary emission, and n = the number of stages. The constant s can be broken down into a function of the working voltage and constants depending upon the various factors of the multiplier such as the type of emitting surface, etc., or

$$s = AV_e^{-pV} \tag{2}$$

where e = 2.718, and V is the voltage per stage. The voltage per stage V can be expressed in terms of the voltage V_o across the whole multiplier in the following manner

$$V = \frac{V_o}{n} \tag{3}$$

Expressing G in terms of this function we get

$$G = \left(\frac{AV_o}{n}\right)^n \times e^{-pV_o} \tag{4}$$

As it is desirous to determine at what value of these constants the gain will be a maximum, it is found mathematically from the above expression, what value of n will make G a maximum, and this is found to be

$$n = \frac{AV_o}{e} \tag{5}$$

Therefore $$G_{max} = e^{\frac{A}{e} - p} V_o \tag{6}$$

In order to determine the constants A and p, use is made of equation (2) and of an experimental curve showing the relationship between s and V for a given surface.

The maximum value of V is found on this curve and its value is substituted in equation (2).

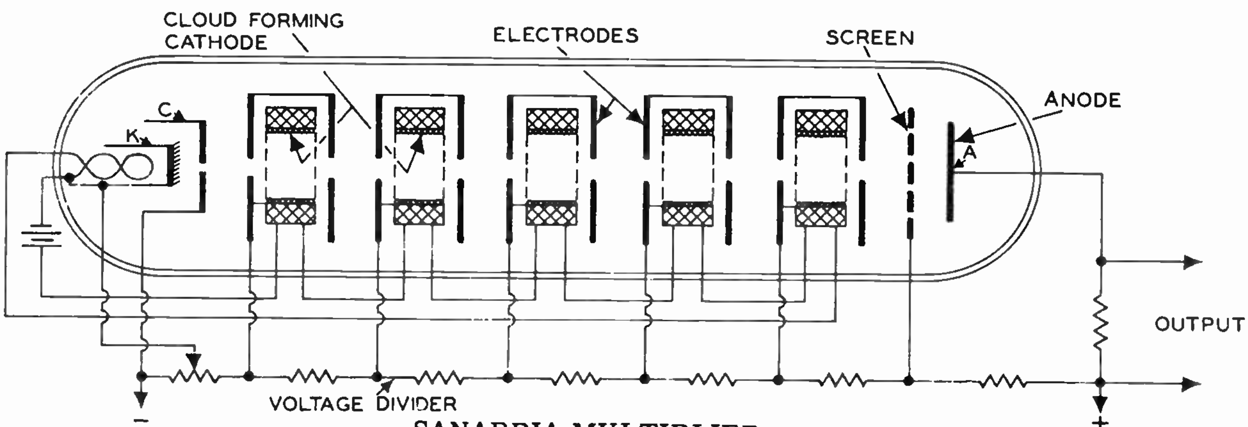
It is also found from equation (2) that s reaches its maximum value when

$$V = \frac{1}{p} \tag{7}$$

The equations given above will hold for any type of Zworykin electron multiplier. There is an additional computation however in a type where electron lenses are employed to direct the emitted electrons. The path of the electron through these varying fields is derived in the same manner as the electron gun and is fully described in the Assignment on electron-optics.

A radically new type of electron multiplier has recently been suggested by Mr. U. A. Sanabria in which the current amplification is electronic throughout.

We have seen that in the ordinary type of electron multiplier whether they be of the Zworykin or Farnsworth type, electron multiplication is accomplished by means of secondary emission, or fundamentally speaking a few primary electrons liberate a great many more secondary electrons from a photo-electric surface. However, energy must be used to liberate these secondary electrons from the photo-electric surface as well as accelerate the electrons. It is easy to see that the energy used to overcome the work-function of the metal or to free the electrons from the photo-electric surface is wasted as far as actual current amplification is concerned.



SANABRIA MULTIPLIER

Figure 14.

The fundamental idea underlying Mr. Sanabria's invention is that of a progressive device in which a small number of electrons at high velocity causes the repulsion of an electron cloud from its cathode, and these electrons are in turn amplified in the same manner.

The tube consists of a primary emitter K and anode A at one end. See Fig. 14. The number of electrons in the beam that is caused by this arrangement being varied by a conventional grid or aperture control, C. Situated next to it along the axis of the tube is a cloud forming cathode. This consists of a cylinder which is coated on the inside with an emitting substance and around the outside of which is wound heater wires. Electrodes are situated on either side of this cathode and charged suitably so that the electron cloud formed by the cathode normally remains within the cylinder. When the high velocity electrons from the primary emitter come within the vicinity of this very dense body of free electrons, a strong electrostatic repulsion is set up and a great many electrons are forced out of the cylindrical cathode space for each primary electron which enters it.

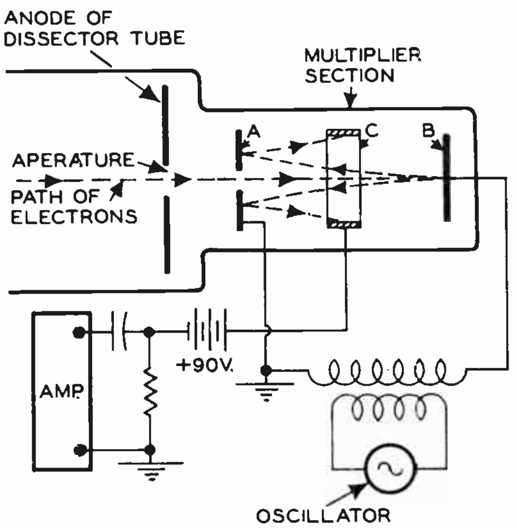
These electrons are accelerated in turn and are focused into a beam into a similar cathode cylinder arrangement. This action takes place progressively through several stages. The number of electrons falling upon the final target plate is many million times the number of electrons in the primary beam.

The gain can be computed for this type of multiplier similarly to the other type of electron multiplier, the gain per stage instead of being dependent upon the voltage and the type of surface, however, is dependent upon the voltage and the density of the electron cloud, together with the actual arrangement of the electrodes.

We have seen how the conventional type of electron multiplier has a very low noise level due to the elimination of the input resistor which is necessary in the conventional type of triode amplifier. However, two sources of noise still remain, one of these is due to the fact that the current flowing in any type of electronic device is composed of discrete particles, and therefore, there must be random fluctuations as these particles arrive at the anode. It will be seen that this noise is fundamental in nature and can not be totally eliminated. In the Sanabria device the effective space charge minimizes this effect, while the other types of multipliers by virtue of their working principle, can not. The other source of noise is due to the electrostatic disturbances set up when the electron strikes the photo-electric surface, and by the very nature of the Sanabria multiplier principle, this source of distortion is eliminated. A five-stage Sanabria electron multiplier is illustrated in Figure 14.

The Farnsworth Multiplier

A diagram of the Farnsworth Multiplier used to amplify the output of the Image Dissector is shown in Figure 15. In the multiplier section are two parallel plates A and B about 4 cms. in diameter and about 6 cms. apart. The plates are coated with a secondary emitting surface of Caesium on Caesium oxide. Between the two plates is located a short cylinder of metal, C, which collects the current which has been multiplied by means of the plates. The electron stream which passes through the aperture of the image dissector enters the multiplier section through a hole in plate A. An oscillating potential is applied across the plates as shown in the diagram. The electrons that pass through the hole when the oscillating potential is going through zero and proceeding to make plate B positive will be attracted to plate B. Upon striking plate B, they will liberate a large number of secondary electrons. The oscillating potential is timed so that one-half cycle corresponds to the time required for an electron to travel from A to B. Hence, when the electron stream strikes B, the potential reverses and the large number of secondary electrons are attracted to plate A. On striking A, a larger number of secondary electrons are liberated and the potential reverses so that the secondary electrons are attracted back to B. A few such reversals will serve to multiply greatly the first few electrons that originally entered the hole. The collector ring C is at a positive potential and will serve to give the multiplied electrons a motion in a direction at right angles to the axis and as a result they will eventually strike the collector. The electrons that reach the collector ring represents the useful output of the multiplier. The output of such a multiplier under the proper operating conditions is quite stable and will give an amplification of at least 1,000. The output of the multiplier now can be handled by the conventional amplifier without trouble.



Farnsworth Multiplier

Figure 15.

Low-Velocity Electron-Beam Scanning

The type of iconoscope thus far discussed employs a high-velocity beam accelerated by a potential on the order of 1,000 volts. From the preceding we may deduce the following information relative to the scanning of insulated surfaces with high-velocity beams.

(1) Redistribution of the secondary emission over the mosaic is an essential part of the the discharge process.

(2) The secondary emission produced by the beam at the mosaic, and the photo-emission from the mosaic are both unsaturated.

(3) The potential swing of an element of the mosaic is limited.

Taking these in order, we find:

(1) The redistribution of secondary electrons is generally not uniform and results in the "dark-spot" or spurious signal. This limits the usable beam current and amplifier gain.

(2) The fact that the secondary emission and photoemission are not saturated reduces the operating efficiency to about ten per cent.

(3) The limited potential swing of an element limits the maximum signal that may be obtained.

In an effort to overcome the limitations encountered with high-velocity scanning, considerable experimentation has been conducted using low-velocity beams. A high-velocity electron beam may be described as one which produces a secondary emission ratio greater than unity, while a low-velocity beam is one in which the electron velocity is not high enough to produce a secondary emission ratio greater than unity. It is therefore evident that an insulating surface is charged positively when struck by a high-velocity beam, and negatively by a low-velocity beam. Yet, each of thse beams may be used to neutralize the positive charges produced on the mosaic by the emission of photo-electrons due to an optical image focused on the surface. A low-velocity beam does this by depositing electrons to replace the emitted photo-electrons. A high-velocity beam discharges such a surface by the more complex process invoving the redistribution of secondary electrons over the mosaic, as already explained.

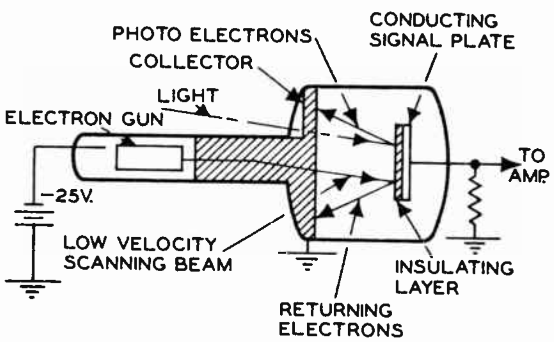


Figure 16.

The diagram in Figure 16 will aid in a preliminary description of low-velocity beam scanning. If the beam current is sufficient, the arriving electrons charge the mosaic surface to the cathode potential, after which no further electrons can strike the mosaic. The collector potential may be high enough to saturate any electron emission from the target; thus, when an element is lighted a saturated photo-emission is drawn to the collector and the element is driven positive during the time when it is not being scanned. When the beam strikes the element again, it drives the potential back to that of the cathode. The charging of the mosaic surface to cathode potential releases a corresponding charge from the signal plate to produce the video signal. In this elementary form. low-velocity scanning avoids secondary electron redistribution since all of the liberated electrons are drawn to the collector. This prevents the formation of a spurious signal. Moreover, the high collecting field saturates both photo-emission and secondary emission, and makes possible an efficiency approaching one hundred per cent. Also, the potential swing of an element may be up to 20 volts or more (although in practice much lower values are found), resulting in greater output.

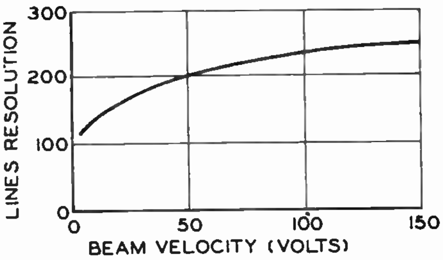


Figure 17.

However, low-velocity beam scanning has several limitations. For example, the simple arrangement in Figure 16 is not practical, since the beam becomes very unstable as it is slowed down to zero velocity near the target. The operation is also markedly affected by wall charges, by small potential differences over the mosaic, and by space charge in the beam itself. These tend to defocus the beam and distort the image. Figure 17 illustrates the effect of defocusing at low-velocity and the consequent reduction in resolution. In development models of this type of device a uniform magnetic field is used for focusing purposes.

It is desirable to have the beam strike all points of the target with the same component of velocity normal to the surface. Suppose this were not so. Then, at those places where the normal component is the larger, the mosaic surface will be charged more negatively. This is shown in Figure 18, which shows a ten-volt beam approaching the mosaic at two different angles. At normal (90^{o}) incidence, the beam charges the surface to -10 volts before the electrons are reflected. At other angles, the potential assumed by the surface will be numerically less than -10 volts. For example, in Figure 18, where the normal component corresponds to eight electron volts, the surface is charged to -8 volts before reflection occurs. Hence, even with no image on the mosaic, a potential gradient may be set up, resulting in a spurious signal similar to that found in high-velocity beam scanning.

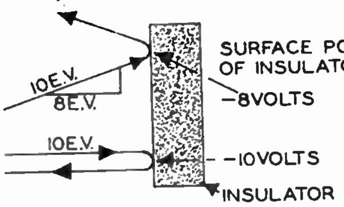


Figure 18.

For low-velocity scanning, higher beam currents (on the order of 2 microamperes) are necessary Difficulties arise here, since heavier beam currents are of larger cross-section, and require larger focusing fields. Also, there is an upper limit to the beam current that may be passed, due to restrictions imposed by space charge. The limitations could generally be avoided by arranging for the beam to move at relatively high velocity until it is near the mosaic where it is slowed down over a short distance to substantially zero velocity.

Further problems arise concerning the deflection of low-velocity beams. If deflection is accomplished in the usual manner before the beam enters the magnetic field, the pattern will be badly distorted by the fringing of the magnetic field. For this reason deflection is accomplished within the magnetic field, and requires a system of unusual design, as illustrated in Figure 19. The image is focused upon a two-sided photo-electric mosaic M, which is immersed in the uniform magnetic field produced by the focusing coil. The flying spot forming the raster of a cathode-ray tube is focused upon a translucent photo-cathode, P. (The light from the cathode ray tube is of constant intensity, i. e., the C.R. beam is not modulated.) The incident of the light from the C.R. tube upon P causes the emission of photo-electrons from the particular area illuminated at any instant. These photo-electrons are accelerated by a cylindrical anode, A, and then scan the side of the Mosaic M facing the C.R. tube. Briefly, then, the spot from the C.R. tube is used to excite P and the resulting photo-electrons perform the scanning in unison with the light from the C.R. tube. Photo-electric beams up to two microamperes have been obtained in this way. Only a negligible amount of lag is noted resulting from the phosphorescent lag of the C. R. tube screen

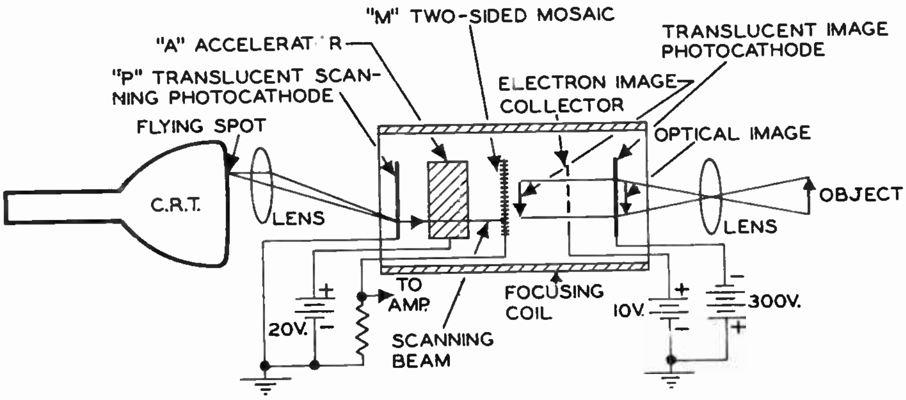


Figure 19.

Electrostatic deflection may also be employed in conjunction with a hot cathode. The plates are immersed in the magnetic field used for focusing, and they must be as wide as the mosaic. That is, the horizontal and vertical plates form a box-like affair (rectangular parallel piped) whose cross-section is equal in area to that of the mosaic.

Magnetic deflection may also be employed in conjunction with a hot cathode. Due to the large fields necessary, experiments to date have confined magnetic deflection to the frame scan, while horizontal deflection is electrostatic. A great deal of additional investigation remains to be done for the purpose of determining optimum designs for low-velocity. Considering its many advantages, especially as regards its negligible spurious signal, higher efficiency and output, this type of device opens new roads towards the progress of television pick-up tubes.

The Image Iconoscope

Another type of iconoscope makes use of secondary-emission electron image intensification, and is illustrated in Figure 20. In this form, the image iconoscope consists of a photocathode, P, upon which is projected an optical image, an electron lens system, L, for focusing the photo-electrons from P onto the mosaic M, and an electron gun which scans the mosaic in the usual way. The photocathode, P, is semitransparent and has a sensitivity between 20 and 50 microamperes per lumen, as compared with the 15 microamperes per lumen of the standard mosaic. One method of preparing the photo-cathode consists of evaporating an extremely thin layer of silver on a glass disc, or directly on the end of the tube. The silver is oxidized and caesiated and finally silver-sensitized. Excellent spectral response can be obtained by proper control of the photo-cathode preparation. For sensitivities on the order of 50 microamperes per lumen, the infra-red response is generally too great, so that somewhat less sensitive films are used in order to yield a more satisfactory ratio of infrared to visible response.

The incidence of the light image upon P causes the imission of photo-electrons which are drawn away from P by the strong field produced by L, which accelerates and focuses the photo-electrons upon the mosaic, M. There thus appears on M an electron image corresponding to the light image, since the emission from P per unit area is proportional to the light intensity. The electron or charge image on the mosaic is then scanned by the beam from the electron gun, and this produces the video signal. The significant feature about the image iconoscope is the fact that for each photo-electron liberated by P, several secondary electrons (ratios from 3 up to 11) are released by M. Hence, for a given illumination the charge built up on the mosaic in a tube of this design is much greater than that on the mosaic of a standard iconoscope. The same statement is true in the case of the iconoscope shown in Figure 20.

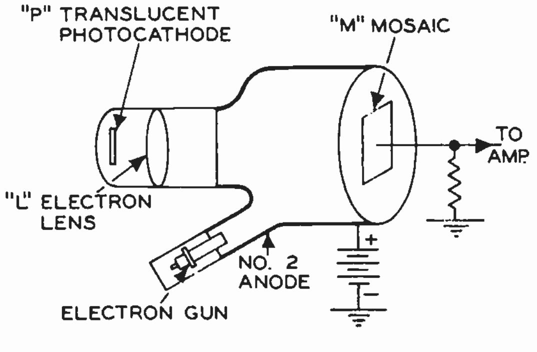


Figure 20.

The electron lens, L, may be either of the electrostatic or electromagnetic type. If the former, there are several coaxial cylinders with successively higher potentials for focusing and acceleration. The final anode voltage of such a lens system ranges between 1,000 and 3,000 volts. At 1,000 volts the resolution of the device corresponds to about 400 lines, while at 3,000 volts is about 800 lines, the limit probably being determined by mechanical imperfections of the lens and photo-cathode.

A magnetic electron lens for this type of tube requires special design. The coil must be large compared to the diameter of the electron image if severe aberrations are to be avoided. To this end it is constructed in such a way that the flux lines close to the photo-cathode approximately coincide with the paths which the electrons would follow if there were no magnetic field. Although relatively unimportant, defects occurring in this type of lens include curvature of field, distortion and chromatic aberration.

The mosaic M may be of the usual iconoscope variety. Or, it may consist of caesium globules with no silver deposited on the mica. This yields greater sensitivity and resolution, but it is more difficult to obtain uniform globules than in the standard mosaic. A third type of mosaic, which is the one most generally used, employs an insulator (china clay) in the form of a finely divided powder covering a metallic signal plate. When suitably activated, this form of mosaic is more sensitive than the others described. Its operation is based on conductivity through the mosaic, a potential being applied between the second anode and signal plate.

The electron gun for scanning is of conventional design, the beam voltage being about 1,000 volts and the beam current between .1 and .2 microampere.

Although the sensitivity of this tube decreases as the voltage on the photo-cathode is increased above 600 to 800 volts, nevertheless, the improved resolution makes it advisable to use from 2,000 to 3,000 volts. Another advantage of employing the higher voltage is that it minimizes the interaction between the electron image and the scanning beam. At and over 2,000 volts this interaction is negligible.

Under comparable operating conditions the sensitivity of the image iconoscope is between six and ten times that of the usual type of iconoscope. Although a spurious signal is generated consequent upon the electrons' redistribution, it is very small compared to that found in the standard form.

The Image Orthicon

The search for more sensitive television cameras is one of the present major research problems of the television manufacturers. Toward this end, RCA engineers have recently unveiled a camera tube claimed to be one hundred times more sensitive than the Iconoscope and Image Dissector tubes already described. The tube, shown in Figure 21, is known as the Image Orthicon. Due to the additional sensitivity, the tube possesses the following advantages:

1. A greater depth of field, thereby permitting the inclusion of background that would otherwise be obscured or blurred.

2. The ability to televise scenes too dark to produce an acceptable image with the iconoscope and image dissector tubes.

Physically, the tube looks like an elongated image projection tube, being approximately 15 inches long and three inches in diameter at the head. Electrically, the tube is divided into three parts: the image section, where the equivalent distribution of charge over a photosensitve surface is formed; a scanning section, consisting of the electron gun, the scanning beam and deflecting coils; and finally, a multiplier section where, through a process of secondary emission, more current is generated than is contained in the returning beam. This action is closely akin to the electron multiplier contained in the Farnsworth Image Dissector. Fig. 22, illustrates these three sections of the Image Orthicon.

In operation, light rays from the scene to be televised are focused by an optical lens system onto a transparent photo-sensitive plate. At the inner surface of this plate, electrons are emitted from each point in proportion to the incident light intensity. Note that the light rays must first penetrate the transparent plate before they reach the photosensitive inner surface.

Figure 21.

The emitted electron image (in which at each point, the density of the electrons corresponds to the light at that point) is accelerated to the target by a positive grid. At the target the impinging electrons produce secondary emission and thus develop a pattern of positive charges directly proportional to the distribution of energy in the arriving electron image. The target is not photosensitive, but it is capable of emitting secondary electrons. Notice that through this method of forming a charge distribution on the target, it is possible to obtain a more intense degree of positive charge distribution than if light itself had been permitted to shine on a photosensitive mosaic, as in the Iconoscope.

The back of the target is scanned by a low-velocity electron beam. This beam is slowed down just short of the plate, and at each point gives up sufficient electrons to neutralize the positive charge at that point. The remainder of the electrons in the beam then return to an alectron multiplier arrangement where several electrons are produced for each impinging electron. The result at the output is a current amplified many times over the current in the return beam.

It is evident that the most positive points on the plate return the least number of electrons from the original scanning beam. Hence, the voltage developed across the output load resistor is inversely proportional to the positive charge intensity on the target. As we shall see presently, this corresponds to negative phase polarity in the signal.

In order to fully appreciate the opertion of the image orthicon, a more detailed analysis of the construction of the two-sided target and its operation is required. In order to function effectively, the two-sided target must be able to conduct electrons between its two surfaces but not along either surface. The logic of this is evident. Whatever charge appears on the one side of the target

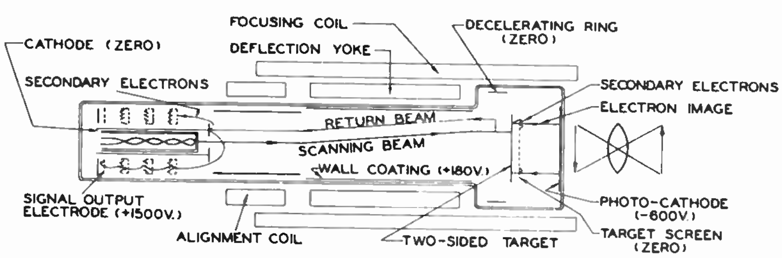


Figure 22.

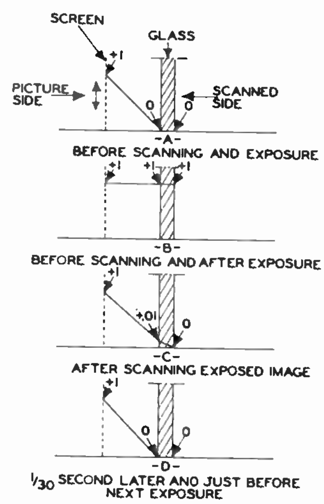


Figure 23.

due to the focused image, must likewise appear on the other side. It is this second side which is scanned and it is from here that the video signal is obtained. Hence, a conducting path must exist between the front and back sides. On the other hand, nothing must disturb the relative potential that exists throughout the charge pattern, as deposited on the front side of the target. Hence, no conduction is permissable between the various elements of any one side of the target plate. Where this occurs, then the charge differences between the various points on the image would disappear.

The two-sided target used in the image orthicon consists of a thin sheet of low-resisting glass. The resistivity between the front and back sides is sufficiently low so that if we were to place opposite charges on the sides, complete neutralization (by conduction) would occur in less than 1/30 of a second. In this way, we prevent one frame from affecting the next frame, an effect which is known as "hangover."

The thin sheet of glass is about 1-1/2 inches in diameter. It is placed about two thousandths of an inch from a flat fine-mesh screen. The purpose of this fine-mesh screen is to collect secondary electrons that are knocked off the target when the photoelectrons impinge upon it. In order not to interfere with the oncoming photoelectrons, the mesh contains 500 to 1,000 meshes per linear inch, an open area of 50 to 75 per cent and a considerable accuracy of spacing.

The variations in potential on both sides of the target during one cycle of operation are shown in Figure 23. In the first illustration, Fig. 23A, both sides are at zero potential, brought to this point by the scanning beam. The fine-mesh screen is purposely held to -1 volt to collect secondary electrons. In the second illustration, the target has been exposed to the light and a positive charge due to the secondary electrons which have been given off due to the photoelectrons from the photo-cathode. The scanned side of the target also is brought to the -1 volt potential due to the conducting path between both sides of the target.

In the last illustration, Fig. 23D, the electron beam has just scanned its side of the target, neutralizing the positive charge. Remember that in this tube the electron beam gives up just enough electrons to neutralize the positive charge. The remainder of the electrons (in the beam) return to the multiplier structure. The picture side, in this third illustration, is not shown at zero volts because of the slight time lag (due to the fact that there is a certain amount of resistance between the two sides) before complete neutralization occurs. By the time the next frame is ready to begin, the charge has been neutralized and the potentials have once more reached zero. This completes one cycle and is repeated over and over again, as long as the equipment is in operation.

CHAPTER V

CATHODE RAY TUBES

Ever since Nipkow originated the idea of dissecting an image by means of scanning, there has been a continuous search for more suitable means of image formation. Thousands of different scanning devices have been invented, most of them mechanical, but the modified Braun tube seems to be the most satisfactory image former invented up to this time. This must not be construed to mean that mechanical scanning is entirely out-dated. The Scophony system in England and several other similar types of mechanical scanning, seem to be equal, if not superior to electronic image formation for large pictures. However, the latter has become by far the most popular system within the last few years.

Fig. 1. A modern cathode-ray tube built at American Television.

The fundamental advantages of the cathode ray tube for television purposes may be summed up in the following sentences:

1. Elimination of all mechanical driving means, therefore absolutely noiseless operation.

2. Only a small amount of power is necessary for deflection and modulation of the cathode ray tube so that the amplifier and synchronization costs are relatively small.

3. The position and brightness of the ray are not controlled by separate units as with a mechanical receiver.

4. As a rule, there are no absorption or aperture losses since no optical lenses are employed.

5. Ideal spatial distribution of light from the picture.

6. The light from the beam can be used without any of it being screened off, i.e., without any loss of screen light.

7. Because of the freedom from inertia of the ray, one can use scanning methods in which sudden changes of the scanning speed are possible.

8. The evenness of the picture raster (the luminous area on the fluorescent screen which is formed by the application of the normal deflecting fields to the electrom beam) does not depend on

expensive, accurately made mechanical parts, but to a first approximation only on the linearity of the deflection.

9. It is possible to scan with varying numbers of lines per picture or pictures per second by simple changes in the circuit values.

10. One can change over to other scanning systems by the use of simple switching arrangements.

11. Cathode ray tubes can be manufactured with simple and cheap components.

The idea of using a cathode ray tube for oscillographic purposes is generally credited to Braun. This German physicist constructed high voltage, cold cathode tubes which he used for oscillographs. At first the electron beam was entirely focused by leaving a small amount of gas within the tube. Later on, this method was used in conjunction with magnetic focusing.

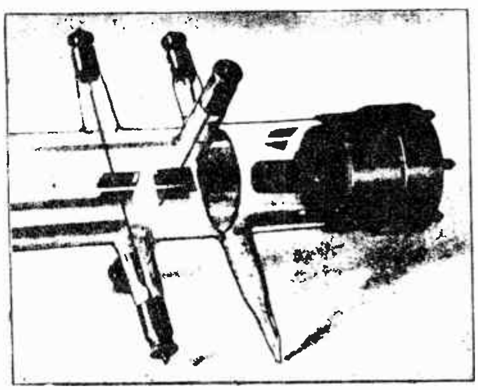


Fig. 2.
A Von Ardenne Tube, 1932.

At that time, little was known about the electron lens method of spot formation and the earlier cathode ray tubes seemed to be very much inferior to mechanical methods of picture reproduction. Then various mathematical analysis were made by several investigators of electron optical systems. Practical tubes were then made embodying the relationships found by various experimenters among whom were Zworykin, Von Ardenn, and others.

In gas-filled tubes, argon gas at pressures of 10^{-2} to 10^{-3} mm of H_g is used. The gas is employed to neutralize the negative charges which accumulate on the walls of the cathode ray tube and to focus the electron beam. Neutralization of the negative charges on the walls of the tube is accomplished by the positive gas ions which are produced when the electrons, streaming from the cathode collide with gas ions.

The focusing action of the gas can be explained as follows: The electrons leaving the cathode are attracted to the screen by a high positive voltage placed on an anode located between the cathode and fluorescent screen. However, due to the presence of the gas, some electrons in the beam will strike the gas atoms, causing the atoms to lose an electron and hence, to acquire a positive charge. The gas atoms, having considerably more mass than an electron, will hardly change position because of this impact. The electrons that are produced by the collision drift outward very rapidly because of their light mass. As a result, a column of positive ions extends down the length of the tube, producing a positive electric field. The direction of the field is such as to force electrons in toward the axis of the tube. This offsets the natural repulsion of the electrons for each other and a well-defined, sharply focused beam is produced.

During the transition period, when gas tubes were being replaced by high vacuum electron lens tubes, a tube which embodied both the systems of focusing was employed. For instance, the tube used by Von Ardenne in 1932 and 1933 used both electron optical methods and gas for focusing purposes. Now gas tubes have some advantages over high vacuum tubes and vice-versa, but the high vacuum tubes have shown themselves to be superior for television purposes and they are the only ones which are in general use today. The advantages of the gas tubes and the high vacuum tubes are listed below:

Advantages of Gas Focus Television Tubes

1. A lower anode potential is required.
2. Tubes possess higher deflection sensitivity.
3. Higher spot brilliancy possible with same anode voltage.
4. The electrode assembly is cheaper
5. Electrode assembly easier to manufacture.

Advantages of High Vacuum Television Tubes

1. Tubes possess a much longer operating life.
2. They are stable during operation.
3. They have extremely better modulation characteristics.
4. They possess better raster contrast.

Discussing the above points briefly and taking them in order. The gas focus tube requires a lower anode potential because a reasonable brilliancy can be obtained at a low potential. The reason that this is so is that the effects of space charge in an electron beam can be neglected in this type of tube. In electron optical systems, however, only a small beam current is allowable otherwise the focus of the beam is destroyed. Therefore, to get the same input power to the screen of the tube, we must use a much higher deflection sensitivity, because of this lower anode potential. The electrode assembly of the gas focus tube, is, of course, much simpler because no complex focusing electrodes are required. It is easier to manufacture, because accurate alignment and formation of the electrodes in an electron optical assembly is essential.

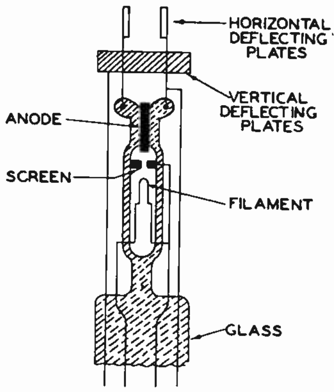


Fig. 3. Electrode assembly W. E. 224

The high vacuum tube possesses a much longer life than any gas focus tube, because in the latter, the emitting surface is destroyed by the bombardment of positive ions, and in spite of all attempts to construct an assembly which would minimize this difficulty, the operating life of the tube is very short compared to the more modern high vacuum type. The high vacuum type of tube possesses a much more stable operating characteristic than the gas focus types. In the latter, charges accumulate on the walls and also spontaneous oscillations in the gas sometimes occurs. Charges are prevented from accumulating on the walls of the high vacuum type of tube by a coating of conducting material (usually a colloidal graphite known as "aquadag" which also has a low light reflection) which also acts as a part of the focusing arrangement and serves to gather the secondary electrons which are emitted by the fluorescent screen. This coating is not used in gas focused tubes, because of the large anode current that would flow.

The modulation characteristic of the gas focus tube is, as a rule, extremely poor. This is because the focusing action of the gas is directly proportional to the electron beam current. Therefore, any attempts to modulate the beam within wide limits will result in serious defocusing. In the high vacuum type of tube, on the other hand, the modulation limits are quite wide, and if the bias and modulation is such that only a small amount of current flows to the focusing electrodes, little defocusing of the spot occurs. When television tubes are mounted in receivers, the fluorescent screen is usually covered by a mask which excludes from view all but the area of the screen which is used by the picture. In a high vacuum tube, which is equipped with good deflecting means this is really unnecessary because the contrast between the raster and the unused portion of the screen is excellent. This is quite different from the gas focus tube where such contrast is unobtainable.

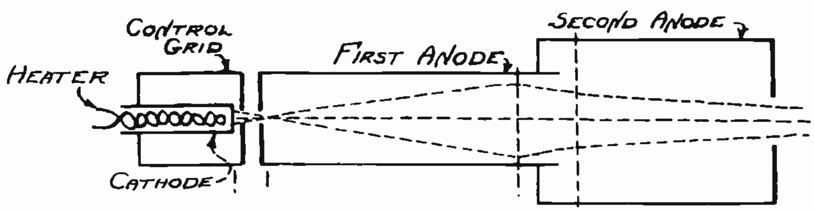
Of the types of cathode ray tubes which can be used for television purposes, we need only speak of the high vacuum tubes. This type can be divided into those which use a magnetic field for focusing the ray, and those which use a system of charged electrodes for this purpose. Then, the tubes can also be classified by the methods which they utilize for deflection purposes. Both electrostatic and electromagnetic means have been used for scanning and some of the most successful systems use a combination of both.

The cathode ray tube occupies the same relative position in the television receiver structure as the loudspeaker does in the sound receiver circuits. Every circuit must be coordinated so that its effect on the signal will fit in with the final function of the receiver -- namely, to reproduce an image which is exactly similar to the transmitted image.

Roughly speaking, the cathode ray tube consists of three sections: The electron gun, where the beam is formed and focused, the deflecting mechanism where the beam is made to sweep across the screen in the proper sequence, and the screen itself where the energy in the beam is converted into an equivalent light intensity. Except for the cathode and control grid, the operation of the cathode ray tube differs considerably from the conventional vacuum tube.

In a cathode ray tube, the electrons emitted from the cathode must be formed into a beam which is projected at the screen. Hence, only the top of the cathode, the section which faces the screen, receives the electron emitting substance. The cathode itself consists of a nickel core upon which is deposited a coating of a mixture of the carbonates of barium and strontium. The cathode, which is yet unactivated, is heated in a vacuum to a temperature much higher than the normal operating temperature. As a result the barium and strontium carbonates decompose to their respective oxides and then the barium oxide is reduced to pure barium to produce a thin layer on the surface of the cathode. It is this thin layer which is responsible for the excellent electron emitting properties of the cathode. Maloff and Epstein have shown that with a cathode of the composition described, the activity will first improve with life and then decrease when the free barium has evaporated.

The electrons, in leaving the cathode, spread out and must be formed into a beam. For this, a system of electron lenses has been devised, one which accomplishes electrically what glass lenses do optically. The elements of a typical electrostatic electron gun using two electron lenses is shown in Fig. 4. This is further broken down into the first electron lens, Fig 5, and the second lens, Fig. 7.



ELECTRON GUN

Fig. 4. The elements of a typical electrostatic electron gun.

First Electron Lens: The first lens system consists of the cathode, the control grid and the first anode of the electron gun. The electrons from the cathode are drawn, by the positive voltage on the anode, into the region between the control grid and the first anode. In Fig. 5 the equipotential lines of the first anode can be seen extending to the cathode. Even if the control grid is made negative, the positive electric field must still be able to overcome this negative charge and present a positive electric attraction at the cathode; otherwise the electrons will never escape from the cathode.

Equipotential lines are merely a short-hand method of illustrating how the electric field about a conductor is distributed. By placing a voltage on the first anode, an electrostatic field is developed around this electode. At various points in the field the electrostatic force will vary. However, as a general rule, at equal distances from the anode the electrostatic force will be the same. This is indicated by drawing a line through all points which have the same electrostatic force. Consequently, the equipotential lines in Fig. 5 show exactly how the field is distributed about the anode. The positive force represented by the equipotential lines attract the electrons at the cathode and force them to travel forward.

The emitted electrons from the cathode must pass through a small opening in order to reach the area between the control grid and the first anode. This, then, is the first method of shaping the electrons into the desired beam. All other electrons strike the solid sides of the enclosure and return to the cathode. From here they eventually reach the beam again.

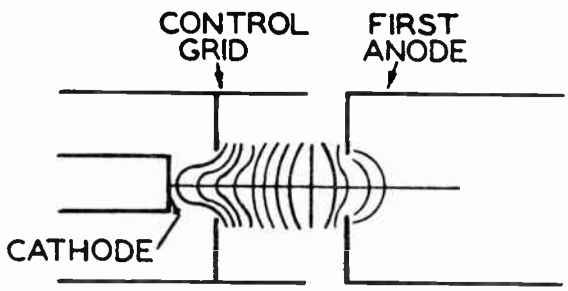


Fig. 5. The first electron lens.

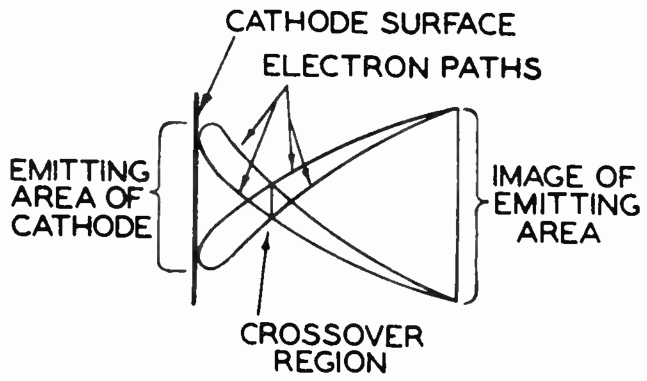


Fig. 6. The crossover region in front of the cathode.

In order to form the electrons which pass through the aperture into a beam, the various sections of the first electron lens are so designed as to force the electrons traveling from the cathode to converge to a small area. This area is situated on the axis of the system, slightly in front of the cathode surface. See Fig. 6. The point where the electrons converge is known as the "crossover" point. From this area the electrons move into the second lens system where they are focused so that they reach the screen in a well-defined point. The electrons are made to converge on the cross over point because then they present a better and more clearly defined virtual cathode and it becomes easier to focus them. We may look upon this area as being a substitute for the original cathode.

Once the beam has been formed, it is the purpose of the control grid to vary the density of electrons reaching this beam. At the screen, this variation produces a proportional variation in the light intensity and the image is produced.

Second Lens System: The second lens system consists of the first and second anodes. Electrons, as they come from the crossover point, tend to spread out. In Fig. 7, the equipotential lines of the second lens system are shown. The diverging electrons entering this electric field are made to converge but the convergence is applied gradually until the electrons are brought together to a point, at the flourescent screen. The design of the elements of the second lens system is such that electrons which are not on the axis of the system are slowly forced to that axis. This is the reason for the curvature of the lines of force. Had they been made so that they extended straight up and down, it would have been impossible to bring them together in a point.

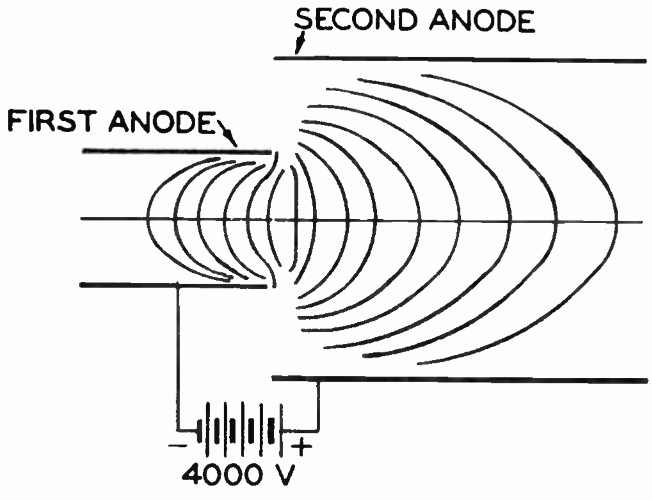


Fig. 7. The second electron lens.

The method of varying the point at which the electrons meet--or the focusing of the beam, in other words--is brought about by varying the potential of the first anode. See Fig. 7. It would have been possible to accomplish the same results by adjusting the potential of the second anode, but the large voltage at this electrode makes this procedure prohibitive. In addition, if we examine the lines of force of the second lens system, Fig. 7, we note that a small change of potential here will have a proportionately larger effect on the direction of the electrons than if the second anode voltage is varied.

Magnetic Focusing: The beam is now focused and ready for deflection. However, before we examine the several methods of deflecting the electron beam, let us consider briefly focusing by magnetic means. Whenever an electron beam enters a magnetic field, a force will be brought to bear on the electron. The only time the force is zero is when the electrons are traveling parallel to the lines of magnetic flux. With magnetic focusing, the focusing coil is placed over the neck of the cathode-ray tube, and just beyond the cathode. When the electrons begin to diverge or spread out after leaving the crossover region, they cut across magnetic lines from the focusing coil and a force is brought to bear on them. The force is such that it is at right angles to the direction of motion of the electrons and to the magnetic lines of force. The path of the electron, under the impetus of this force, is a spiral, with one (or more) complete revolutions or circles completed by the time the electron reaches the fluorescent screen. See Fig. 8.

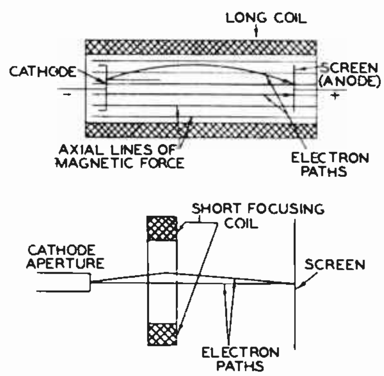


Fig. 8.
The path of the electrons with magnetic focusing.

The electrons leave the cathode at varying speeds, but the time required for any electron to complete the circle in its spiral flight depends upon the strength of the magnetic field and on the ratio of the electron charge to mass. Since all of these quantities are the same for all electrons leaving the cathode, all circles will be completed in the same time. The only effect that the different initial speeds will have will be in the radius of circle traversed by each electron. However, any electron from the cathode will complete its circle in the same time.

It is more practical to use a short focus coil, rather than one which extends the length of the neck of the tube. The short coil applies sufficient twisting to each electron to have it more toward the axis. Its forward motion then keeps it traveling in this direction.

Beam Deflection

Electrostatic Method: The electrons, after they have been properly focused, are next subjected to a deflecting force. This force, like the focusing, may be accomplished either electrostatically or electromagnetically. We shall consider the latter case first.

To deflect a beam electrostatically, two sets of deflection plates are employed. One set of plates are shown in Fig. 9A. The second set is mounted at right angles to those shown. The electrons, in passing through the two sets of plates, are subjected to the electric field established between them and deflected accordingly. To obtain the proper pattern on a cathode-ray screen, for television, a saw-tooth shaped deflecting voltage is necessary.

It would be instructive, at this time, to determine the relationship which exists between the distance the beam is deflected, at the screen, and the deflecting voltage needed to accomplish this deflection. Let us consider one set of deflection plates, say those shown in Fig. 9A. The voltage placed across the plates can be labeled V and this would be our deflecting voltage. To deflect the beam upward, we would apply our voltage in such a manner as to make the top plate positive with respect to the bottom plate. The distance between the plates is h.

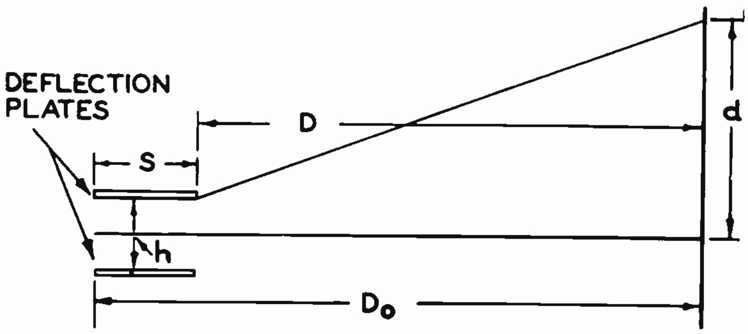


Figure 9A - Electrostatic deflection of an electron beam.

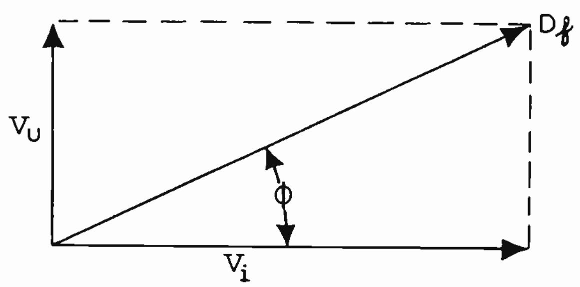


Figure 9B - Velocity components after leaving deflecting field.

Therefore, the electric intensity between the plates is

$$\frac{V}{h}$$

Now, the electrons in the electron beam possess a certain velocity by the time they reach the plates. They have been attracted from the cathode and accelerated down the tube. At the plates, they are subjected to two forces: (1) the forward motion which they received in order to reach the plates and, (2) an upward attraction produced by the positive top plate. The result is neither a straight forward motion or an upward motion, but a combination of the two. If we consider only the upward attraction produced by the positive top plate, we have

$$\text{acceleration} = \frac{V}{h} \cdot \frac{e}{m}$$

where

e = charge on the electrons
m = mass of the electron
V = deflecting voltage between plates
h = separation of the plates.

It will be evident, after a little thought, that the value of the acceleration will depend also on how long the electron remains between the plates. Remember, though, that the electron has a forward motion and so will remain between the plates for a time equal to

$$t = \frac{s}{V_i}$$

where

s = length of the deflection plates
V_i = forward velocity of the beam

Now, if we take this time, which is all the time the deflecting voltage has in order to accomplish its purpose of deflecting the beam, and multiply it by the upward acceleration noted above, we will obtain the upward velocity.

$$a \times t = \frac{V}{h} \cdot \frac{e}{m} \cdot \frac{s}{V_i}$$

The ratio of the upward velocity, V_u, to the forward velocity, V_i, form two sides of a right triangle, as shown in Fig. 9B. This same ratio is maintained after the electrons pass the deflection plates. That is, the electrons now have two forces working on them and as a result of these two forces, the electrons move at an angle to the main axis. The path is given by the hypotenuse of the right triangle formed in Fig. 9B. The distance along the base of the right triangle is the distance from the center of the deflection plates to the screen. The vertical distance upward, at the screen, denoted by D_f, is the distance the beam was deflected.

We have here, then, two similar right triangles and from plane geometry the following ratio can be set up.

$$\frac{\text{Upward Velocity of Beam}}{\text{Forward Velocity of Beam}} = \frac{\text{deflection distance}}{\text{distance from plates to screen}}$$

or,

$$\frac{V_u}{V_i} = \frac{D_f}{D + \frac{s}{2}}$$

The quantity, $D + \frac{s}{2}$, is the distance from the center of the deflection plates to the screen. The center of the deflection plates is chosen in order to arrive at an average value. Actually, the deflection of the beam becomes as soon as the plate region is entered.

Substituting for V_u in the above equation, we have

$$\frac{\frac{V}{h} \cdot \frac{e}{m} \cdot \frac{s}{V_i}}{V_i} = \frac{D_f}{D + \frac{s}{2}}$$

Rearranging terms produces

$$D_f = (D + \frac{s}{2}) \frac{V \cdot e \cdot s}{hmV_i^2}$$

Now, V_i^2, the forward velocity can be shown to be equal to

$$V_i^2 = 2E\frac{e}{m}$$

where e = charge of an electron
m = mass of the electron
E = accelerating voltage between cathode and deflection plates.

Substituting for V_i^2, above,

$$D_f = (D + \frac{s}{2}) \cdot \frac{Vs}{2Eh}$$

This is the equation which governs electro-static deflection.

The expression indicates that the deflection of the beam is directly proportional to the deflecting voltage V (applied to the plates) and inversely proportional to the separation between them. Furthermore, the deflection must take into account the acceleration given the electrons, E, before they reach the deflection plates. A conclusion immediately indicated is that less deflecting voltage is required when the beam is traveling slow than when it has been highly accelerated. This is certainly logical since the longer the electron remains between the plates, the longer the deflection voltage is effective and the greater the beam displacement.

In characteristic tables of cathode-ray tubes, the foregoing factors are combined into a deflection factor or a deflection sensitivity. Both units provide the same information, but from a different viewpoint. For example, for a 20AP4 tube, the deflection sensitivity is given as 1.2 mm/volt kv. as an average value. In expanded form this means that with 1,000 volts (1 kv) on the second anode as the accelerating voltage (E in the above equation), 1 volt difference between the deflecting plates will move the beam 1.2 millimeters at the screen. Since the deflection sensitivity is inversely proportional to second anode potential, raising the anode voltage to 2,000 volts will decrease the displacement of the beam to 0.6 mm. By doubling the accelerating voltage, we have halved the deflection sensitivity.

Instead of noting how far a beam is moved by one-volt change across the deflecting plates, we could determine how many volts are required to displace the beam one inch on the screen. For the 20AP4, the answer is 22 d.c. volts/inch/kv. and this would be known as the deflection factor to differentiate between it and the previous unit. To convert from one unit to the other, it is only necessary to know that there are 25.4 millimeters in one inch. Hence, if one volt at the deflection plates moves the beam 1.2 mm. at the screen, we divide the 1.2 into 25.4 to see how many volts would be required to move the beam one inch. The answer is 22 volts.

On the other hand, if we know that it takes 22 volts at the plates to move the beam one inch at the screen, then we can divide 25.4 by 22 to determine how far the beam will move when only one volt is at the plates. The answer is 1.2mm.

D.C. volts are specified since this eliminates any confusion concerning the exact number of volts. A.C. volts must be qualified by such terms as average, peak, effective and more often than not these are omitted, leaving no indication as to the proper value.

Electromagnetic Deflection: We have already seen that a magnetic field exerts a force on a moving electron and this leads quite naturally to the deflection of electron beams by means of magnetic deflection coils. It is almost universal practice today to employ electromagnetic deflection with tubes which possess screen diameters of 10 inches or more. The advantage of this form of deflection is that it provides a considerable amount of deflection with only nominal amounts of power. As a result, the cathode-ray tube can be shortened and the deflection coils utilized to swing the beam through as much as 55°. Similar action in a tube having electrostatic deflection would require an excessively high voltage. If electrostatic deflection is attempted using only a reasonable deflection voltage, it would be necessary to make the distance from the plates to the screen fairly long, resulting in an oversized cabinet.

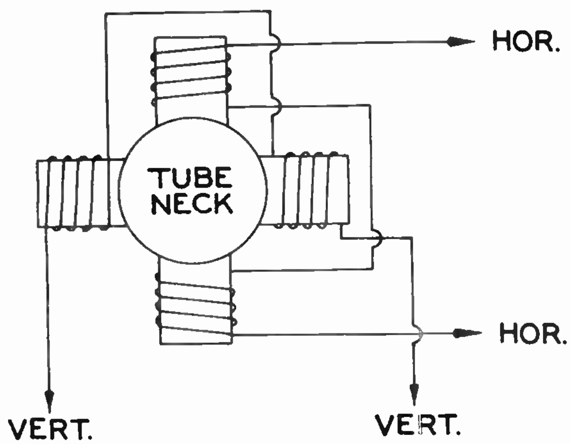
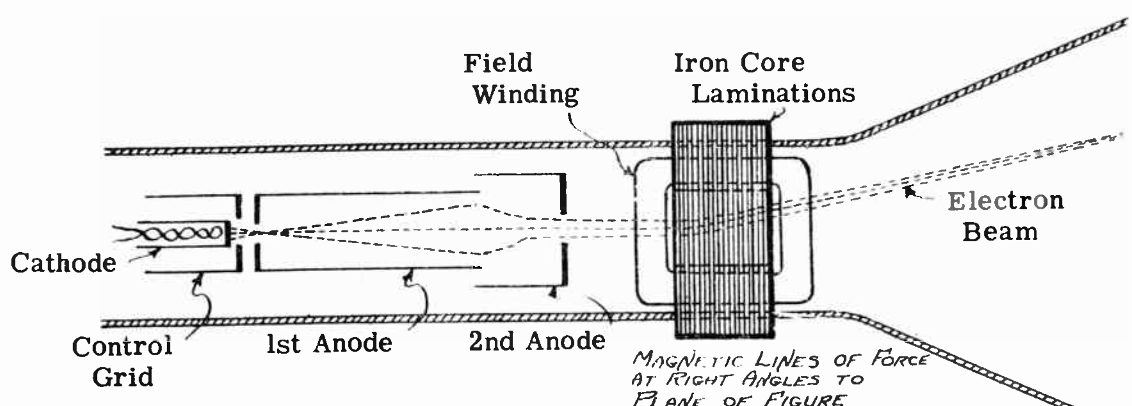


Fig. 10.

To produce the magnetic deflecting field, two sets of coils are placed at right angles to each other and mounted on the section of the tube neck where the beam leaves the focusing electrode and travels toward the screen. There are two coils in each set, as shown in Fig. 10, with oppositely placed coils comprising one set. These are connected in series. A soft iron shell encases all the windings, effectively shielding the coils from outside fields and, at the same time, strengthening the desired deflecting flux. It is well to note that the horizontal deflecting coils are vertically placed whereas, for vertical deflection, the coils are horizontally mounted. The necessity for this arrangement arises from the fact, previously stated, that the force on a traveling electron in a magnetic field is at right angles to both the direction of electron motion and the magnetic lines of the field. See Fig. 11.

In fitting the deflection yoke--this being the technical name for the coil and its iron enclosure-- the serviceman will have to rotate the unit until the image is properly oriented on the screen. The tube, itself, will not require any positioning adjustment. When electrostatic deflection is used, it is impossible to alter the position of the plates. In these instances, the tube itself must be rotated.



MAGNETIC DEFLECTION

Fig. 11.

A mathematical analysis of magnetic deflection indicates that the distance the beam is shifted or displaced on the screen is governed by

$$d = \frac{D L \epsilon H}{m v}$$

where H = the strength of the magnetic field
e = change on the electron
m = mass of the electron
v = forward velocity of the electron

The remaining factors in the above equation are illustrated in Fig. 12. The equation, through the relationship of the various items, demonstrates that the deflection, d, is

1. Inversely proportional to the velocity of the electron.
2. Inversely proportional to mass of the electron.
3. Directly proportional to the magnetic field.
4. Directly proportional to the length of the deflection coil and the distance from the coil to the screen.

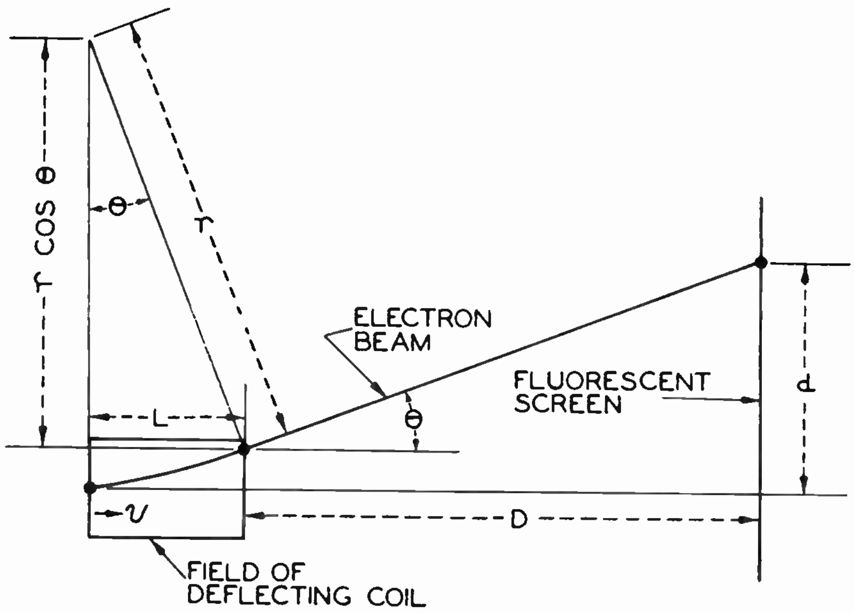


Fig. 12. Electromagnetic deflection.

Beam Defocusing

Electric and magnetic fields are employed for deflection and focusing and consequently it is reasonable to assume that any stray fields cutting across the tube will affect the beam. To prevent this occurrence, it is either necessary to shield the tube, or if this is impractical at least to position it so that the probability of stray fields reaching the tube is materially reduced. If a metallic shield is decided upon, one should be obtained which will fit as snugly as possible about the tube to reduce the area actually occupied by the tube and prevent it from becoming too bulky.

There are additional sources which lead to image distortion or beam defocusing, the latter especially occuring at the edges of the screen. It may readily happen, for example, that the electric field between the deflecting plates, or the magnetic flux generated by a coil is not symmetrical with respect to the axis of the tube. As long as the beam remains at or close to the tube axis, very little distortion will be evident. However, the unbalance will greatly increase with increased displacement from the axis and with this will appear the defocusing.

Another defect, and one which exists only in magnetic deflection tubes is the appearance of a dark spot at the middle of the screen of the cathode-ray tube. This spot is the result of negative ions, formed by a gas molecule acquiring a negative electron. These gas molecules are much heavier than an electron and as such are not as readily affected by a magnetic field. This is evident from the formula governing deflection by magnetic fields. The ions form a beam and are focused in the same manner as the electrons. However, since they are less sensitive to magnetic deflections than the electrons, they will generally impinge at the center of the screen. By continually bombarding this one region, they tend to destroy or disintegrate the screen, rendering it incapable of responding to the electrons or forming an image. In electrostatic deflection systems, however, the ions receive the same deflection as the individual electrons and are deflected through the same angle as the electrons.

The reason for the differing effect can be obtained from an inspection of the equations governing deflection electrostatically and electromagnetically. For the electromagnetic deflection, we have

$$d = \frac{D L e H}{m v}$$

while for electrostatic deflection, the expression is

$$d = \frac{1}{2} \times \frac{V}{E} \times \frac{s}{h} \left(D - \frac{s}{2}\right)$$

In one instance (electromagnetic) the mass of the deflected particle appears in the equation while in electromagnetic deflection it does not. Hence, the ions, because of their greater mass, will not receive the same deflection in electromagnetic systems that the electrons will receive. However, when the mass of the particle does not affect the final deflection, the ions will be bent through the same angle as the electrons.

Electron Optics

The electron gun and its function in forming and focusing an electron beam has just been briefly considered. With this overall picture in mind, it is now possible to investigate the beam formation and focusing in greater detail, this time employing the laws of electron optics.

WHAT IS ELECTRON OPTICS? Electron optics may be defined as that division of the electronic art which deals with the controlling of electrons in a vacuum in such a manner that desired images are formed on a fluoresent screen. However, this definition is not quite broad enough, because sometimes these electron images are not converted into a form of light, but are analyzed electronically. For example, a case where this action is utilized is in the television pick-up camera such as the "Image Dissector" tube.

Speaking in familiar terms, the electrons emitted by a cathode (usually heated) are directed along desired paths by a combination of electrostatic and/or magnetic fields.

In more exact modern terminology, the electrons act like waves in the ether, whose paths are determined by the refractive fields through which they pass.

The History of Electron Optics. -- The theoretical development of electron-optics begins with the mathematical discovery of Sir William Hamilton that a charged partical moving through disturbing fields would act similarly to a ray of light passing through media with varying refractive indices.

The next major step was the experimental discovery in 1927 by Davisson and Germer that electrons underwent diffraction when they were reflected from nickel crystals, thus tending to show that if the electron was not entirely wave-like in nature, at least it was partly so, and the belief has grown more and more prevalent that all matter exhibits a dual nature, that of the wave and the particle.

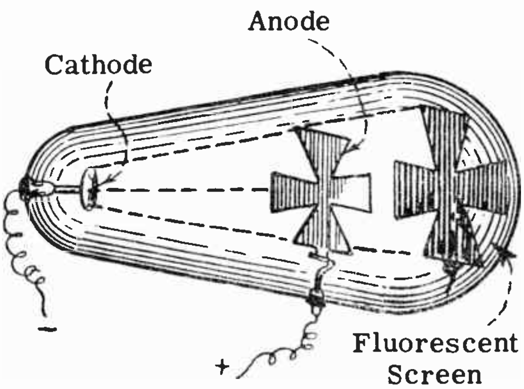


Fig. 13.

G.P. Thomson, son of the physicist, J.J. Thomson, corroborated this theory of electronic structure by showing how electrons formed haloes when passed through metallic films. This is exactly similar to the action of light when passed through very thin films, and when Thomson calculated the wave-length associated with the electron from his experimental data, his evidence was indisputable.

The famous mathematical physicist, DeBroglie, enlarging upon the theories of Planck, Bohr, Sommerfield, and Einstein, had already published his theory on the "wave-like" properties of matter. This theory was further developed by Schrodinger, Heisenberg, and Dirac. This theory is now generally accepted and a whole science has grown around it which is commonly called, the new "Wave Mechanics." It has been extremely successful in explaining the exceedingly complex photo-electric phenomena, and many other points which proved to be the downfall of the classical theory.

The first experimental evidence of the reality of the light like properties of electrons was probably exhibited in the Crookes' tube. (Fig. 13) In one of the variations of the tube, the anode consisted of a Maltese cross, and the electrons leaving the cathode in straight lines and impinging upon the anode end of the tube wall, caused fluorescence, but showed a definite shadow of the anode structure. Another form of this type of tube was built in which the cathode was a concave structure and if a small ball of platinum was placed near its center of curvature, the electrons proceeding in straight lines normal to the cathode surface would come to a focus at this point, and the metal would be heated to incandescence by the bombardment of the rays.

Probably the first and best known person to experiment with cathode ray beams was the German Physicist, Braun. He mainly used very high voltage tubes with cold cathodes, and used the residual gas in the tube to complete the focus of his electron beam, so that no real work was done on focusing electrons by means of electron optical methods.

Several attempts were made to use this type of focus, but nearly all of them were "hit or miss" propositions, because the calculations involved were complex and there was really no important practical use for cathode rays at that time.

Then, in 1926 and 1927, some articles appeared in the periodical, Ann. Der Physick by Bush, which gave a theoretical analysis of a narrow beam of electrons traveling in an evacuated tube, and showed that the beam would focus in any non-uniform magnetic or electric field provided that the fields had an axial symmetry with respect to the beam.

The same periodical in 1932 contained some articles by Knoll and Ruska and several others dealing with simplified cases of thin electron lenses.

More recently, Picht extends the analysis to a case where electrons are assumed to travel through a continuously varying electrostatic field. His analysis, however, is not of great practical value owing to the fact that it depends upon exceedingly complex functions which are difficult to obtain.

Several experimental scientists working on a more practical side of the art had developed electron guns suitable for practical purposes. Of these, we can mention Zworykin, Von Ardenne and Farnsworth. In addition to this, a theory has been worked out notably by Epstein which was of a more practical nature and which had been checked against actual experimental values.

There are two branches of "electron-optics" which are similar fundamentally but differ quite radically in practice. The first of these is the case in which it is desirous to focus the beam into a small well defined spot. This is the function of the electron gun which is used in television receiving tubes and the iconoscope. The other branch is where it is desirous to form a more complex image.

WHAT IS AN ELECTRON GUN? An electron gun is a device, the purpose of which is to form a small well defined "spot" on a fluorescent screen or on the image plate of an iconoscope. (See Fig. 14A.) It might be thought that all that is necessary to form this type of electron image is to accelerate a thin beam of electrons. However, the electron bears a charge, and when a group of electrons travel down a tube, they tend to repel one another and so spread apart no matter how well defined the beam originally was. Therefore, many systems have been devised which originally spread the electron beam apart and then bend the paths of the individual electrons so that they tend to arrive at a common point at a certain distance. In other words, to focus the electron beam. In order to do this, an arrangement of electrodes or magnets are used which are termed electron lenses. If electrostatically charged electrodes are utilized, it is called an "electrostatic lens". If magnets are used, it is called a "magnetic lens". Fig 14 shows electrostatic focusing of the electron beam.

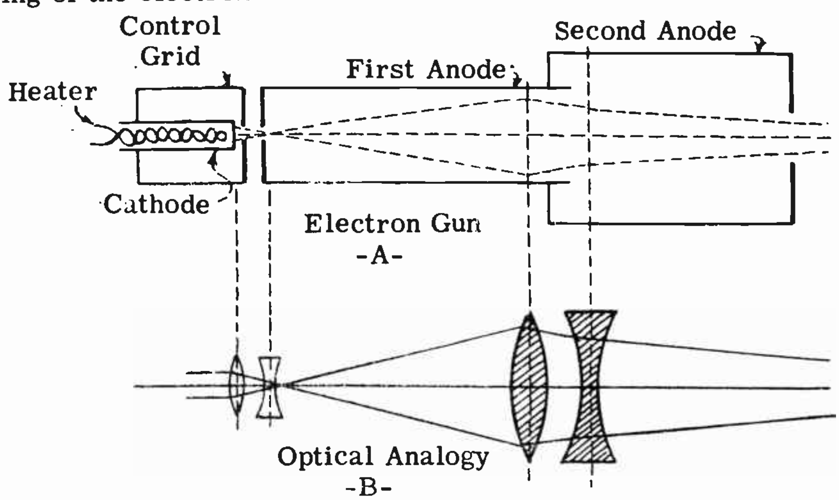


Fig. 14. The electron gun and its optical analogy.

The electrostatic lens (Fig. 14A) usually consists of coaxial cylinders of different diameter and at different potentials. However, this is not always the case. Any electrode having axial symetry such as a cone or other complex surface may be used for the purpose. There are four types of electrostatic lenses, namely, uni-potential lenses, by potential lenses, aperature lenses and immersion lenses. The latter type of lens is usually found associated with the cathode-grid potential distribution.

The Optical Analogy (Fig. 14B) The system of two cylinders (Fig. 14A) which are used for focusing purposes in an electron gun, (a bi-potential lens), may be compared to the optical system of Fig. 14B with one important difference. In an optical lens, the boundary surfaces are well defined and the refractive index changes abruptly from one value (that of air) to the other (that of glass). In the case of the electron lens, however, this is by no means the case. The refractive index continuously varies from one value to the other, and it may be compared more correctly to an optical thick lens. Fig. 15A shows an electrostatic refractive field, and Fig. 15B shows its optical analogue.

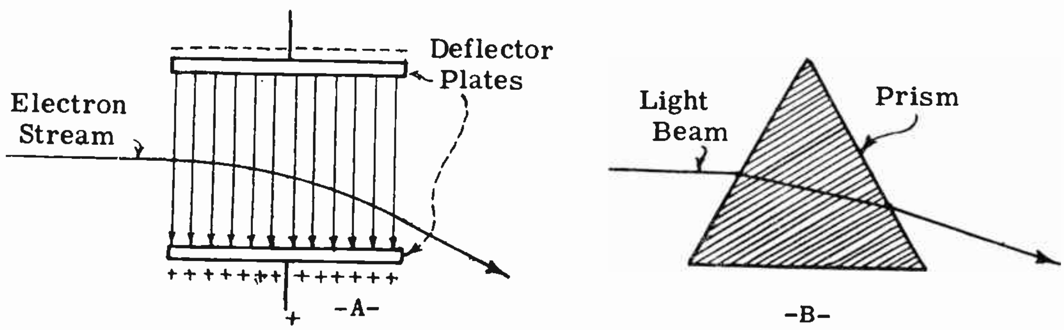


Fig. 15. Deflection of electrons. The bending of the light beam is shown for analogy.

In calculating the properties of an electron lens, we compare it to an optical lens with a definite instead of indefinite surface, and an abruptly changing, rather than a continuously changing index of refraction.

The direction that an electron is refracted, that is, whether an electron beam is brought to a focus or diverged, depends upon the potential-difference between the two cylinders, and whether it is positive or negative; that is, whether the potential-gradient tends to accelerate or decelerate the electron, depending upon whether the potential-gradient is positive or negative. Generally speaking, if the field is accelerating, the lens is a converging lens, but if the field is decelerating, it is a diverging lens depending also, of course, upon the configuration of the electrodes. The electrode construction of Fig, 17 represents a converging lens, if Anode No. 2 is at a higher positive potential than Anode No. 1.

HOW TO DETERMINE THE PATH OF AN ELECTRON THROUGH AN ELECTRON LENS SYSTEM BY A GRAPHICAL.METHOD. The first requirement for this method is to determine the lens configuration, that is, the curvature of the lens or lenses in the system. This can be accomplished by locating so-called EQUI-POTENTIAL points and EQUI-POTENTIAL lines in the lens system. There, we must learn the method of charting the lens configuration.

METHOD OF CHARTING THE LENS CONFIGURATION. The configuration of the lens can be experimentally determined by charting the equi-potential lines. This is accomplished by means of the arrangement shown in Fig. 16. An enlarged cross-sectional model of the electrode structure, built to scale of conducting material, is placed in a tank containing water of low conductivity, ordinary tap water will suffice in most cases. Fig. 16 shows the arrangement. The model electrodes should not be completely immersed, they should partly extend above the surface of the water.

If voltage is applied across the model electrodes, a small amount of current will flow through the water from one electrode to the other. The water in this case acts as an ordinary resistor. As a result, at various points in the water between the electrodes we could locate different values of voltage or potential in exactly the same manner that different values of voltage or potential can be located on a voltage divider. The object in this case is to determin the potential of a great many such points in the liquid and plot a line through all points that are of equal potential to form what is called an EQUI-POTENTIAL LINE. The measurement of the voltages at the various points is accomplished by an ordinary Wheatstone Bridge arrangement, as shown in Fig. 16. The voltage for the electrodes is obtained from the tapped resistor AB which, in turn, receives its voltage from the 400 cycle AC generator. The tapped resistor CD serves as one side of the bridge. The other side is from A through HIFKL to B. Point E is connected through a pair of headphones to a probing rod at point F. When the probing rod at F touches the surface of the water, a signal is heard in the headphones. The adjustable tap at E is then moved until no signal is heard in the phones. At this point, the potential at F will be equal to the potential at E. The probing rod can then be moved through several different points (equi-potential points) at which no signal is heard. If the probing rod is on the end of a pantograph arrangement as shown in Fig. 16, the motion of the probing rod can be reproduced by a stylus (G) attached to the other end of the pantograph. This stylus or mapping pencil moves over a drawing of the electrode sturcture of exactly the same size as the model and placed as shown in the figure. Several different equi-potential lines can be obtained by changing the setting at E and locating the new places at which no signal will be heard in the headphones. A chart of the equi-potential lines will appear as shown in Fig. 17.

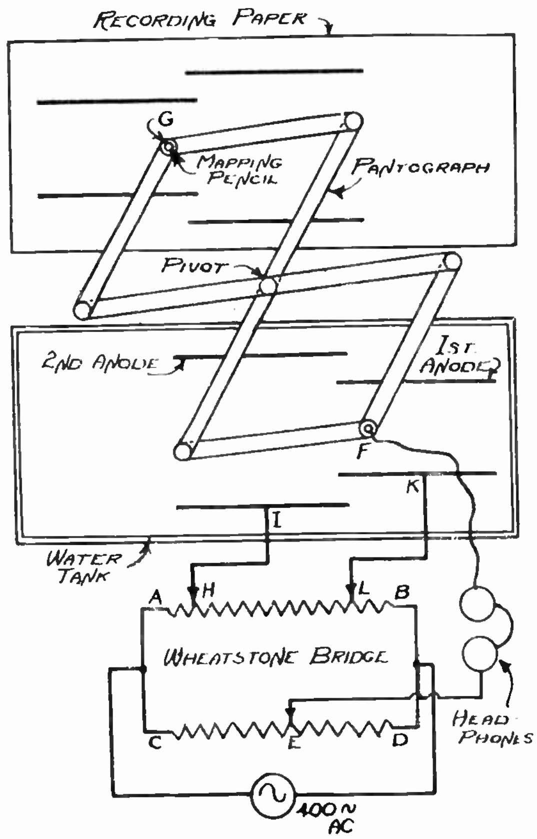
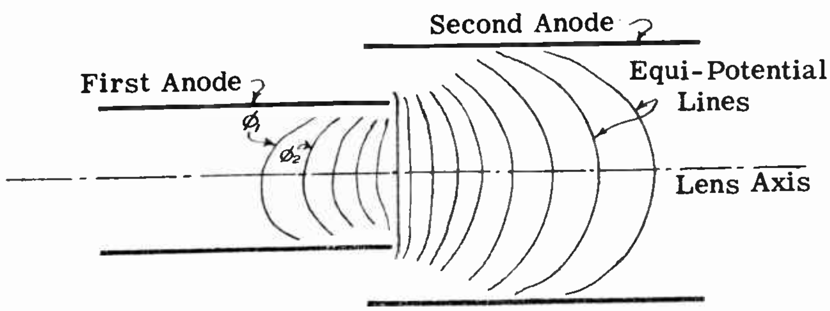


Fig. 16.
Plotting the distribution of the lines of force in an electron gun.

When an electron flows through the lens system of Fig. 17, each equi-potential line, or equi-potential surface will serve to refract or change the direction of a light beam. Therefore, by a graphical method, we must determine the amount of refraction at each individual surface until the electron stream has progressed through the entire electrostatic lens field.



Bipotential Electron Lens

Fig. 17. The second electron lens.

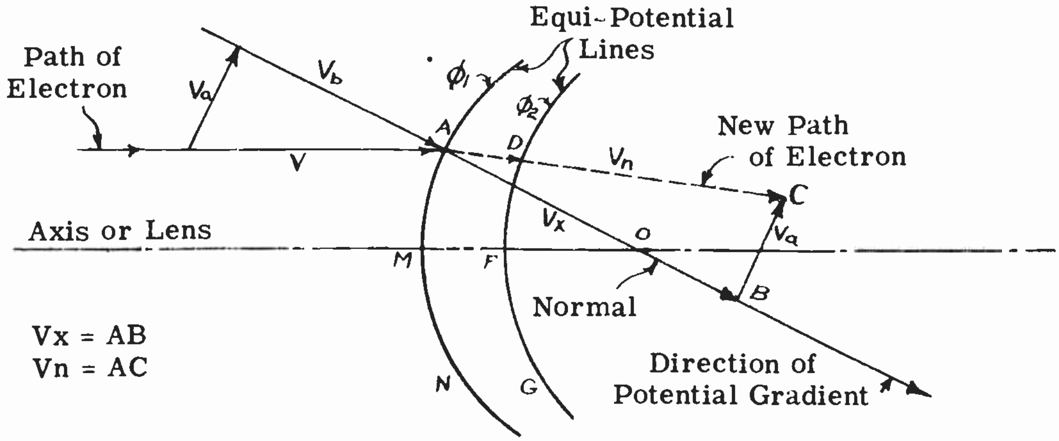


Fig. 18.

Now, to go back to the most simple case where the electron is moving parallel to the lens axis.

Fig. 18 shows the path of the electron parallel to the axis of the lens striking the first equi-potential line or surface AMN at point A. The curvature AMN was obtained from Fig. 17 (ϕ_1). The curvature ϕ_2 of Fig. 17 is shown in Fig. 18 as DFG. At point A (Fig. 18) draw a line OAB that is normal to the curve AMN. In other words, draw a line through point A that would be perpendicular to a tangent of curve AMN at point A. This normal to the equi-potential line represents the direction of potential gradient and the electron will be acted upon by a force tending to pull it in this direction. The direction of potential gradient is shown in Fig. 18. Let the original electron velocity be represented by some convenient length V, Fig. 18. Then draw a line V_a from the left extremity of V perpendicular to an extension of line AOB. Now then, V_a represents the component of velocity at right angles to the potential gradient, and V_b represents the component of velocity in the direction of the potential gradient. Inasmuch as the electron is acted upon by a force in the direction of the potential gradient, the component V_b will change in value after the electron strikes point A. No force acts in direction V_a, hence the component V_a does not change. If we can determine the amount that V_b changes, we shall be able to find out the new direction of the electron.

For light, we know that the index of refraction of two substances is equal to the ratio of the velocities of light in the two substances. This also holds true in electron optics; that is, the index of refraction P for an electron lens is equal to the ratio of the velocities of the electron when traveling through the lens and when approaching the lens. It has also been proven in electron optics that the index of refraction of an electron lens is given by the relation

$$P = \sqrt{\frac{\phi_2}{\phi_1}}$$

where ϕ_2 and ϕ_1 are the potentials of equi-potential lines as shown in Fig. 18. In such a case, we must consider an electron moving from a region at potential ϕ_1 through a narrow region into a region at potential ϕ_2.

For purposes of calculation, let us assume that ϕ_1 was found by the Bridge method to be ten volts and that ϕ_2 was found to be 20 volts. Substituting these values in the relation for Index of Refraction, we obtain

$$P = \sqrt{\frac{\phi_2}{\phi_1}} = \sqrt{\frac{20}{10}} = \sqrt{2} = 1.414$$

We also know that P equals the ratio of the velocities of the electron in the two media, hence let us call the new component of velocity V_x. Notice that only the component V_b of the original electron velocity will be affected.

Hence, our ratio of velocities is expressed as follows:

$$P = \frac{V_x}{V_b} = 1.414$$

Solving for V_x , we find that

$$V_x = 1.414\ V_b$$

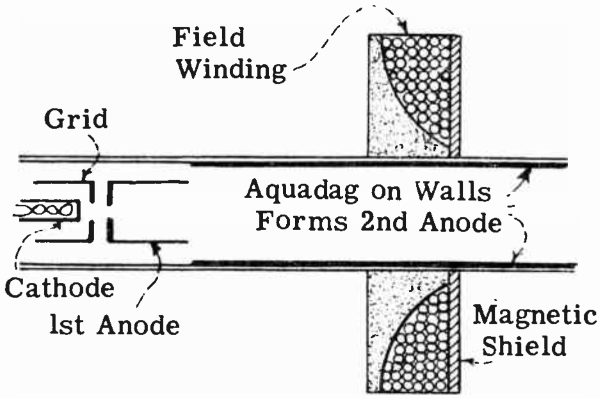
Now, lay off a length of line V_x that is 1.414 times as long as V_b along the direction of of the potential gradient so that it appears as line AB, Fig. 18. Line AB now is a component of our new velocity. The component V_a of the original velocity did not change and appears unchanged in our final velocity. At point B, erect a perpendicular AC to line AB that is equal in length to line V_a. We now have the two components of the final velocity, namely V_x and V_a. A line drawn through the extremities of the two components will represent the final velocity and its direction. In Fig. 18, line AC represents the final velocity.

So far, we have determined how the electron is affected when it strikes the first equi-potential line in its path. Our next step would be to proceed from point D where the electron hits the second equi-potential line in exactly the same manner as for the first. For example, draw a normal to curve DFG at point D, find the components V_a, and V_b etc. The same procedure is carried out for each individual equi-potential line encountered. Bear in mind that the region between successive equi-potential lines must be narrow for this procedure to give suitable accuracy.

The foregoing description deals only with the main lens of the system. A practical electron gun, however, consists of several lenses. (Refer back to Figure 2) The first lens being made up of the control grid and first anode, the lens like properties of the cathode grid field configuration being somewhat masked by the effect of space charge. The so called grid in a cathode-ray tube is usually not a grid at all and is more properly termed the control electrode. It consists of cylinder in which is mounted a perforated disc. This structure surrounds the cathode and is commonly known as a "Wehnelt cylinder." When the potential of this electrode with respect to the cathode is varied, the intensity of the electron beam passing through the aperature varies in proportion and thus, the brilliancy of the spot on the screen varies likewise. This is how a television picture shown on a cathode-ray tube is actually formed, together with the scanning deflections. It is interesting to note that while the lens like properties of the cathode grid configuration is partly neutralized by the effective space charge, it is not entirely so, and if the potential of the control electrode is varied within wide limits, the focus of the beam will also be found to vary. Opinions differ in television circles as to whether this detracts or adds to the quality of the television picture, but there is no doubt what ever that it is an added effect or distortion which must be compenstated for.

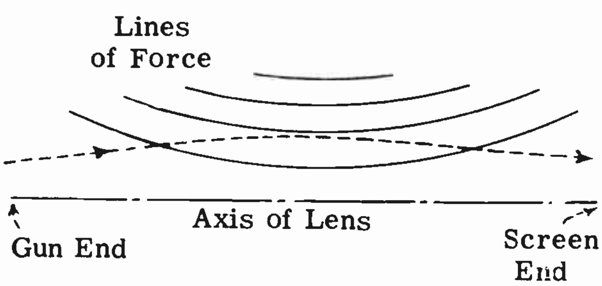
In an electron lens of the type described, there are several causes for aberration. The first and most important of these imperfections is due to the size and position of the emitting surface of the cathode. The spot formed on the screen of a cathode-ray tube, in most conventional guns at least, is an image of the emitting surface, and unless this is small and regular, there will be corresponding departure on the part of the image on the fluorescent screen.

The obvious correction for this trouble is to have a small depression in the end of the cathode, which is packed with the emitting substance, the rest of the cathode being stripped of any emitter. The next cause of difficulty is termed "spherical aberration" due to the similarity of this imperfection in electron lenses as compared to optical lenses. This aberration arises from non-symmetrical electrodes, perfect symmetry being hard to attain. It can also arise from any other mal-distribution of the field. Another distortion present is due to "chromatic aberration" which is due to the electrons which comprise the beam having different velocities. Naturally, when they pass through a common refractive medium, they are refracted to a differing degree and the focus point is therefore much less distinct. In fact, due to these different distortions, the spot on the screen is usually not actually the focus of the electron beam as a whole, but more properly speaking, the disc of least confusion. Stops are used to minimize aberration.



MAGNETIC FOCUSING LENS

Fig. 19A



MAGNETIC FOCUSING

Fig. 19.B

WHAT IS A MAGNETIC ELECTRON LENS? A magnetic electron lens usually consists of a coil which is placed about the neck of the cathode-ray tube (on the outside of the bulb, because of the difficulties concerning high-vacuum technique). The magnetic electron lens of Fig. 19A is designed to reduce spherical aberrations.

When a magnetic lens is used, a system of electrodes is constructed inside the bulb which will cause a narrow beam of electrons to be emitted. The magnetic field which is coaxial with the electrode arrangement being used to bring the beam to a focus. The magnetic field acts in very much the same manner as the electrostatic field.

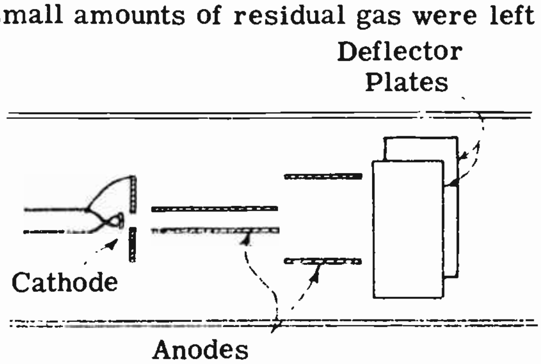
It differs, however, from the electrostatic lens in that it not only focuses the electron beam, but it also rotates the beam about its axis. In other words, if the electron image at the cathode was a line in a vertical direction, it would turn it toward a horizontal direction to a degree depending upon the magnetic force of the lens . Thus, the magnetic lens corresponds to a crystalline medium in optics such as tourmaline while an electrostatic lens corresponds to a non-crystalline medium such as glass. These two types of media are known technically as "anisotropic" and "isotropic" respectively. (Anisotropic--having different physical properties in different directions.) (Isotropic--having the same physical properties in every direction.)

This rotation of the magnetic type lens, while it does tend to introduce additonal aberrations, is not usually important in electron guns, because as the image is a spot, rotation about its axis does not matter. However, in an image forming electron lens, it becomes quite important and in order to maintain the image erect, it is either necessary to insert the whole path of the electron in a uniform magnetic field such as is done in the Farnsworth "image dissector tube" or to have two magnetic lenses so arranged that their rotations are in the opposite direction, and the effect is, therefore, cancelled out. When the configuration of a magnetic lens is to be found, fine iron filings are used in the conventional manner to show the field. The cardinal points of a magnetic lens are found in exactly the same manner as in the case of the electrostatic lens.

However, the magnetic lens has one tremendous advantage in commercial production due to the fact that it is located outside of the tube itself, and therefore, it can be so arranged that any small inaccuracies in the gun construction may be neutralized by proper compensation.

The action of the magnetic field in focusing the electron beam may be stated briefly as follows: (Refer to Fig. 19B). The lines of force of the magnetic coil at the gun end slant in toward the axis of the tube as you progress farther from the gun toward the screen and they slant in the opposite direction at the other end of the coil. When the electrons enter the magnetic field, they tend to follow the magnetic lines of force and so are converged. When they leave the magnetic field, they tend to diverge. The converging action is by far the greater, however, so that the action of the lens on the whole is to converge the beam. The exact explanation of the action of the magnetic lens is quite complex. This is largely due to the fact that a magnetic line of force, unlike an electrostatic line of force does not attract the electron along it, but deflects it in a direction at right angles to the lines of force and the electron path.

Before the advent of the electron gun, which uses electron lenses to focus the beam, small amounts of residual gas were left within the cathode-ray tube envelope to accomplish the same thing. One of the more familiar types of commercial oscillographs which utilize this method of focusing was the WE224A which used a low pressure of argon for this purpose. (See Fig. 20)



GAS FOCUS TUBE

Fig. 20.

In order to form a spot on the screen using this type of focus, an electrode assembly is used which will emit a narrow beam of electrons. As these electons progress down the tube toward the screen, they tend to repel one another due to their mutual negative charge, and if the tube were thoroughly evacuated, a blur would appear on the screen instead of a sharply defined spot. However, an entirely different action takes place when a small amount of gas remains within the tube envelope. When the electron beam goes down the tube, a few of the electrons strike the gas molecules, and in doing so ionize them, (Break them up into positively charged molecules and electrons). The electrons which leave the molecules are traveling with a very high velocity, and so consequently, become diffused throughout the tube. However, the slower moving gas molecules remain in essentially the same position. When the cloud of negatively charged electrons pass around a positively charged molecule, their paths are drawn together by the mutual attraction, and when this takes place down the length of the cathode-ray tube, the repelling action of the electrons toward each other is cancelled out by the attractive force of the positively charged ions, and the beam becomes focused. The more electrons there are in the beam, the more positively charged ions there will be, and consequently, the beam is brought to a focus near the electrode assembly. Therefore, in a gas focused tube, the point of focus of the electron beam can be governed by changing the cathode emission. While in the gas focused tube, because of its simplicity is very useful as a commercial oscillograph, it is practically useless as a television picture reproducer. In television it is necessary to vary the brightness of the spot on the screen of the cathode ray tube, and this is done by varying the amount of electrons which are contained in the beam. We have just seen however that when the number of electrons in the beam of the gas focused tube is varied, the focus varies also, and consequently, any attempt to modulate a beam of this kind results in a proportional defocusing action.

The electron lens focus tube is tremendously more practical for television purposes, because it can be modulated within certain limits without changing the focus appreciably. In fact, theoretically speaking, it should be possible to construct an electron gun, the focus of which is independent of the modulation. Most commercial guns, however, are by no means as perfect as this. The reason being that the modulating electrode tends also to act as a lens in the electron optical system. The value of this lens changes with the modulation voltage. Therefore, you can see that there will be a slight change in the size of spot on the screen, besides its intensity, when the tube is modulated.

Cathode-Ray Screens

The phenomenon of luminescence was known for a long time but its practical application dates only from the middle of the nineteenth century. During this period and leading to its application in the first cathode-ray tube (1907), Becquerel, Stockes and other contemporary investigators determined quantitatively many of the relationships between the phosphorescence of a material and the method of inducing this phosphorescence. Aside from the rather crude application of the tube of 1907, however, nothing extraordinary was accomplished until the early 1930's when European engineers, notably those of the Philips Company in Holland, evolved tubes which, in many respects, are the same as employed today in our latest television receivers.

The phenomenon of producing light when electrons impinge on a fluorescent screen is known as luminescence. Fluorescence is luminescence which ends when the excitation (in this case, the electron beam) is removed. Phosphorescence is luminescence which exists after the excitation agent has been removed. The time differential is approximately 10^{-8} seconds.

The reason for the luminescent property is not completely understood but there is sufficient data available to permit the evolution of a fairly consistent theory. We know, from our study of physics, that the neucleus of an atom is surrounded by moving electrons. These electrons are all in definite paths, each path representitng a certain energy level. In order to move an electron from one level to a higher level, energy must be given to that electron for the transfer to be made. The energy must be sufficient to cause the electron to move, otherwise none of that energy will be absorbed. When the energy is of the proper amount, the electron (or electrons) absorbing the energy will travel to paths of higher energy levels. The entire atom, in this condition, is said to be in an excited state. The emission of light, such as we see on a television screen, is due to the fact that the displaced electron returns to its normal path and releases the absorbed excess energy in the form of light. What the color of that light will be depends upon how much energy the electron absorbed in the first place.

The material which is coated on the inside of the screen is known as a phosphor. In television, the phosphors used are crystalline inorganic substances. Fluorescence takes place when these phosphor crystals receive the proper radiation, such as ultra-violet light, x-rays, alpha particles, or just plain electrons. The energy of each of these activating agencies is absorbed by the electrons in the crystalline structure of the phosphor and light is emitted when the electrons return to their normal or unexcited state. The length of time that it takes an electron to return to its normal state will depend upon the crystalline structure of the substance and the percentage of impurities which are present. Screens made from materials which require a longer time to return to the normal state are known as long persistence screens.

Manufacture of Phosphors: When a phosphor is manufactured, extreme care must be taken to see that its contents do not vary in production. It is the impurities present in the phosphor crystalline structure which give it its desirable properties of luminescence and small changes in the concentration of this impurity will greatly alter the properties of the phosphor. The curves shown in Fig. 21 illustrate this latter point very readily. The relative energy content of each of the different combinations is illustrated. It is interesting to see that the luminescent color, as emitted from the screen, is not the same as the natural color of the substance such as seen when not under bombardment. Remember this when working with cathode-ray tubes.

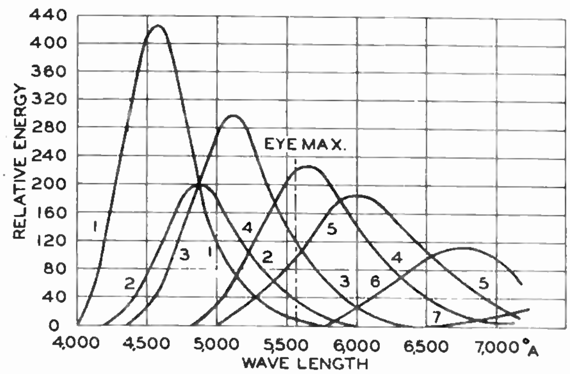


Fig. 21.

There are three different types of phosphors which find extensive application in television cathode ray tubes. These are:
1. sulphides; 2. silicates; and 3. tungstates. (They are listed in the order of their importance.)

The general procedure for manufacturing a given phosphor can be summarized as follows;

1. Purifying the raw materials. -- The safety precautions may seem excessive, but they are warranted when the previous illustration is recalled showing how easily the properties of a phosphor are altered when an improper amount of activating substance is used. The raw materials are checked at each stage of their preparation. The water used is tested many times a day for content and even the air in the plant is passed through numerous filters.

2. Mixing the phosphor contents together. Once combined, the resulting substance is then precipitated out from solution. In precipitating out of solution the substance crystallizes.

3. Heating the result of step 2, to firmly bind the various phosphor components together. The temperatures used are high, being in the region of 800 to 1,300°C. As a result of the heating or firing the complete crystalline structure is formed incorporating within itself the added impurity which is responsible for the luminescent properties.

After the phosphor has been manufactured, it must be reduced to the proper fineness and applied to the viewing end of the cathode-ray tube. The methods of application consist of: (1) dusting; (2) settling; (3) spraying; (4) electrostatic depositing; (5) flowing-on. Each name is fairly indicitive of the method of application. In the fourth method, a strong electric field is produced by the insertion of a charged electrode into the tube. The air becomes ionized, the charge of the air particles are then repelled fromthe electrode and deposited on the bulb. The latter is grounded. After the phosphor has been deposited firmly on the inner surface of the bulb, the aquadag coating is applied. The tube is then placed in an oven and dried thoroughly by heating at 400°C. Phosphors, in the process of manufacture, absorb a considerable amount of gas. When the electron gun structure and deflecting electrodes (if electrostatic deflection is employed) are assembled in the tube, these gases must be removed. During the exhaust process, the tube is heated in an oven at 400°C. At the same time, the filament and cathode are heated by the passage of current through the filament. The final step is the sealing off of the completely evacuated tube. The tube is then operated for a short time in an aging process.

A compilation of the most commonly used screens, and their designation, is given in Table I.

TABLE I

RMA Designation. Substance	Activator	Formula	Fluorescent Color	Phosphorescence (seconds)
P1 . . . Zinc silicate	Manganese	$Zn_2SiO_4.Mn$	Green	Med. .03-.05
P2 . . . Zinc sulfide	Copper	ZnS.Cu	Blue-Green	Long
P3 . . . Zinc beryllium silicate	Manganese	$ZuBeSiO_3.Mn$	Yellow-Gr.	Med. 0.05
P4 . . . P3 and sulfide	Silver	ZnS.Ag - P3	White	Short 0.005
P5 . . . Calcium tungstate	- - - - -	$Ca\ WO_4$	Blue	Very short, 5 u-sec., med. .005
P6 . . . Zinc sulfide Zinc cadmium sulfide	Silver Silver	ZnS.Ag ZnCdS.Ag	White	
P7 . . . Zinc sulfide Zinc cadmium sulfide	Silver Copper	ZnS.Ag ZnCdS.Cu	Blue Yellow	Med. 0.006 Long
P11 . . Zinc sulfide	Silver with a nickel quencher.	ZnS.Ag.Ni	Blue	Very short, 10 u-sec.

C.R.T. Designations: There is in current use a standard system of numbering cathode-ray tubes. The system has been evolved and approved by the RMA and is employed by substantially all radio and television tube manufacturers. The method of numbering cathode-ray tubes is as follows:

1. The first number of the tube designation gives the overall diameter of the fluorescent screen.

2. The last letter and number following it indicate the type of screen and its characteristics. See Table I.

3. Any letters between the first number and the last letter (P) indicate that the manufacturer has modified the internal structure of the tube without changing either the screen diameter or the type of fluorescent screen.

Applying the foregoing rules to a commercial tube, 10EP4, we note that the tube has a 10 inch screen and a P-4 fluoresent coating, the type which is used in television. The E in the tube designation serves to distinguish this tube from any other 10P4 tube which was not constructed exactly the same way. However, all tubes containing the 10P4 designation would have the same screen diameter and identical types of fluorescent screens.

Cathode-Ray Projection Tubes

It is a common desire, and certainly an understandable one, to have large pictures in the receiver. Toward this end, cathode-ray tubes have been developed with screen diameters up to twenty inches. A 20-inch tube, however, requires a considerable amount of space and not all of this large surface area is available for image use. The curvature of the screen limits the image to the flatter portions of the screen, near its center, and the useful image is seldom larger than 12 by 16 inches. Commercially, the 20-inch tube probably represents the largest direct-viewing tube that it is desirable to manufacture. The solution to larger images thus must be obtained by some other process and several such methods have been evolved.

Perhaps the most obvious means of obtaining large images is by projecting the image appearing on the screen of the tube onto another screen by means of a system of lenses. This method is entirely analgous to that employed in movie projection cameras, where the detail on a small 35 mm strip of film is enlarged to the size of a screen many square feet in area. The arrangements of the several components in this system is shown in Fig. 22. The image is projected onto the back of a translucent screen and is viewed from the front by the observer or group of observers.

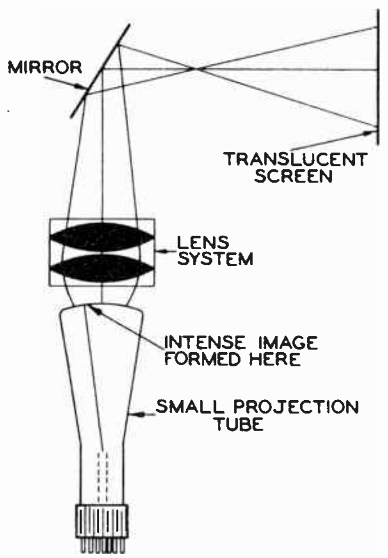


Fig. 22.
A simple projection system using a magnifying lens unit.

In the movie projector, an intense electric light or carbon arc generates sufficient light to present a clear image on the screen, the latter many times a considerable distance from the projector. In television, the image to be projected must first be formed on the fluorescent screen of a cathode-ray tube. With present techniques in the manufacture of such screens, images as intense as those which can be readily obtained in a movie projection unit cannot be formed. This is unfortunate, at the present time, since it greatly reduces the usefulness of a lens projection system. Even with cathode-ray tubes which have been specially designed for such purposes the intensity of the final image is much less than what can be obtained with a simple home movie camera. The transmission efficiency of a conventional optical lens system seldom exceeds 5 to 10 percent, which means that the strength of the image formed on the cathode-ray tube must be increased above its ordinary intensity 10 to 20 times.

The Schmidt Optical System

The idea of using optical means for obtaining large screen images has recently been given added impetus by the application of another system, the Schmidt system. This system is illustrated in Fig. 23. As originally employed in astronomical telescopes, the system consists of a correcting glass lens, a large spherical reflecting surface or mirror and a photographic plate. As the light rays from the distant stars enter the telescope, they pass through the correcting lens, and are reflected by the spherical mirror onto a small photographic plate. Through this means, the light from the stars are concentrated onto the photographic plate and a clear, bright image is formed. The purpose of the correcting lens is to counteract the spherical aberration of the spherical reflecting surface. Spherical aberration is a form of optical distortion and results in a poor focus of the incoming light rays. Through the use of the correcting lens, the spherical aberration is reduced to a negligible degree.

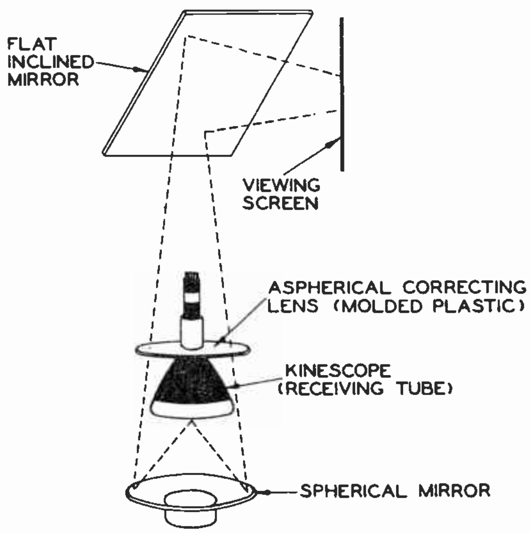


Fig. 23. Application of the Schmidt system to television.

The source of light and the receiving screen in light systems are interchangeable. Hence, a cathode-ray tube can be placed at the point of covergence of the light rays occupied by the photographic plate in Fig. 23 and the images on this fluorescent screen reflected from the spherical surface, through the correcting lens and projected onto a translucent screen. In this form, the system is adaptable for television receivers. See Fig. 24. To maintain as high a degree of light intensity as possible, the surface of the spherical reflector must be kept free of all dust particles.

A careful evaluation of projection images, as compared to direct viewing indicates the following:

1. Brighter images can be produced on direct viewing screens.

2. The angle of vision of a direct-viewed image is greater than the image on a projection screen.

3. Large images can be obtained more economically and in a smaller cabinet structure than a comparable image produced by direct viewing.

The projection images are of good quality and those currently available are recommended for purchase. A 16 x 20 inch image can be easily and comfortably viewed by a roomful of people.

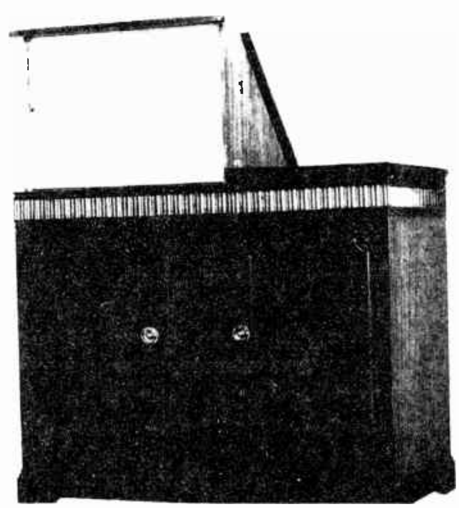


Fig. 24. Large screen television receiver

CHAPTER VI

R-C CIRCUITS

In the field of television, there are uses to which R-C networks are put. It is important, therefore, that we thoroughly understand how these R-C networks function, an understanding which is not only needed to design sets, but also to repair them.

USES:

1. Series R-C circuits are commonly used for coupling between voltage amplifier stages.

2. Series R-C circuits are used for "decoupling" amplifier stages to prevent regenerative feedback. In this application, the R-C circuit is used to filter out undesired voltage variations.

3. Series R-C circuits are used in television to differentiate (change the shape of) complex waveforms (square waves, sawtooth waves, etc.) A complex wave is the result of the addition of two or more sine waves. Small values of R and C are used in these cases.

4. Series R-C circuits are used in television sets as integrating circuits. In these circuits the voltage used is taken from across the capacitor.

5. Series R-C circuits are used in the production of sawtooth wave forms. Only the most linear portion of the capacitor charge curve is utilized.

6. Series R-C circuits are used as hum-removing filters in low current drain rectifier power supplies.

7. The series R-C circuit is used to control the frequency of certain types of oscillators. Among these are the Wein bridge oscillator, the phase shift oscillator and a relaxation type of oscillator known as the multi-vibrator.

FUNDAMENTAL LAWS CONTROLLING SERIES R-C CIRCUITS. - - Any analysis of series R-C circuits must satisfy simultaneously all four of the following laws.

1. KIRCHOFF'S SECOND LAW: The algebraic sum of all the voltage drops around a closed circuit equals zero at any instant.

2. OHM'S LAW:

$$I = \frac{E}{R}$$

3. COULOMB'S LAW: The voltage across a capacitor becomes greater as the amount of stored charge is increased. It becomes less if the capacitance (ability to hold a given charge or number of electrons) is increased. Stated mathematically, the law looks like this:

$$E_c = \frac{Q}{C}$$

4. SERIES LAW: The current is the same in all parts of a series circuit at any given instant.

Because these laws have been firmly established for so many years, the student may feel free to use them in analyzing the action of any series R-C circuit without fearing that they may be repealed.

The operation of series R-C circuits will be studied first under transient conditions.

TRANSIENT CONDITIONS

DEFINITION: For the purposes of explanation during this discussion, a transient voltage will be considered as a random change of voltage. Examples of this are the sudden voltage changes produced by the closing of a switch or a flash of lightning. A transient may be thought of as a sudden surge, in contrast to the steady state condition which will be considered to be a periodically recurring waveform.

Series R-C circuit action usually can be more easily explained by describing the effect of applying a transient voltage to the circuit. Whatever the polarity of the transient at the first instant of application, the capacitor will begin to assume a charge which will oppose the charging voltage.

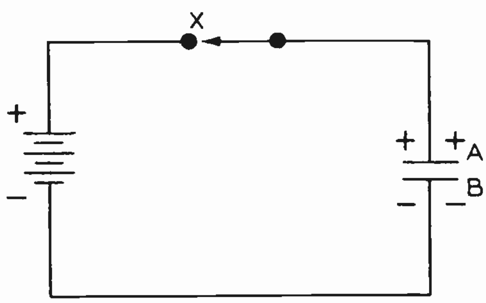


Fig. 1

This is shown in Fig. 1, where the sudden closing of switch X provides the transient voltage. The positive terminal of the battery is a point at which there is a deficiency of electrons. As soon as the terminal is connected to plate A of the capacitor, it finds the electrons are ready to leave this capacitor and attempt to overcome that deficiency at the battery terminal. Furthermore, since electrons repel one another, those on plate B repel those on plate A. In turn, since there are now fewer electrons on plate A, plate B can acquire some new helpers, since there is less opposition. It can be seen that this will proceed in the form of a vicious circle. However, intuition also tells us that there must be a limit. This limit is reached when electrons have vacated plate A to the extent that there is as great a deficiency here as at the positive terminal of the battery. When such a condition has been reached, there is no current flow in the circuit. Furthermore, the algebraic sum of the two voltages (battery and capacitor) is zero, indicating that they are of opposite polarity. This is known as a <u>charge cycle</u>.

However, if the battery were reduced in voltage, electrons in the wire would be attracted by the higher positive potential of the plate A of the capacitor. Therefore, there would be current flow back into the capacitor until its deficiency once more equaled that of the positive battery terminal. If the battery were reduced to zero voltage, then all of the electrons which had previously been evicted would return to plate A, reducing the voltage across the capacitor to zero. Finally, if the battery were actually reversed in polarity, it can be seen that such a reversal of electron flow would continue until the voltage across the condenser decreased to zero and then assumed a charge of opposite polarity. Any of the three conditions which tend to rob the capacitor of the charge obtained during the <u>charge cycle</u> will produce what is known as the <u>discharge cycle.</u> Thus it becomes necessary to consider <u>both</u> the charge and discharge conditions in a series R-C circuit. Consider first the charging action, observing how the afore mentioned laws of Ohm, Kirchoff and Coulomb hold true when (1) zero voltage is applied, (2) the instant full voltage is applied, and (3) some time later (voltage still applied).

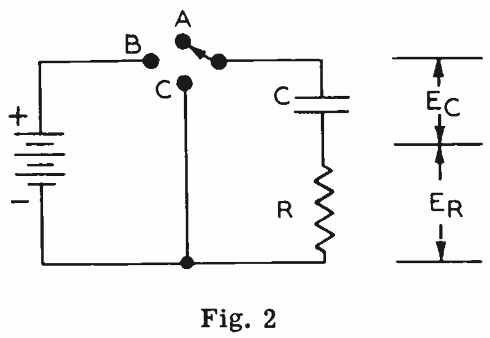


Fig. 2

Remember: <u>All four laws must be satisfied at all times.</u>

CHARGING ACTION: 1. Switch Open (position A). Observe Fig. 2 which shows the switch open. It is obvious that there is zero current and consequently, that E_c is zero and E_R is zero.

2. Switch Closed (position B). 1st instant. When the switch is moved to point B, Fig. 3, electrons

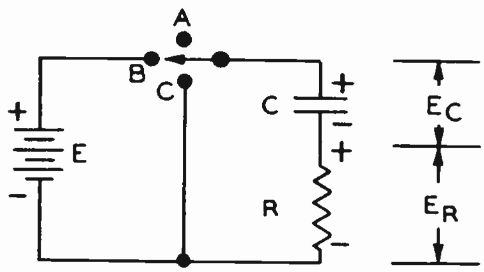


Fig. 3

are attracted from the upper plate of the condenser, C. At the instant current begins to flow, there is no voltage on the capacitor; therefore the battery voltage E across the battery must appear as a voltage drop across the resistor. The inital current, then, must be equal to E/R. While these facts seem simple, they contain information which is highly important to the complete understanding of this circuit. Let us, therefore, analyze each step in detail. At the first instant no time has elapsed. Since the electrons have not had time to accumulate in the form of a charge on the capacitor, then:

$$E_c = \frac{Q}{C} = \frac{0}{C} = 0$$

This is one way of looking at it. There is however, another explanation which means the same thing. As is well known, the higher the frequency applied to a capacitor, the lower is its reactance; in fact an infinitely high frequency sees an infinitely low reactance in said capacitor.

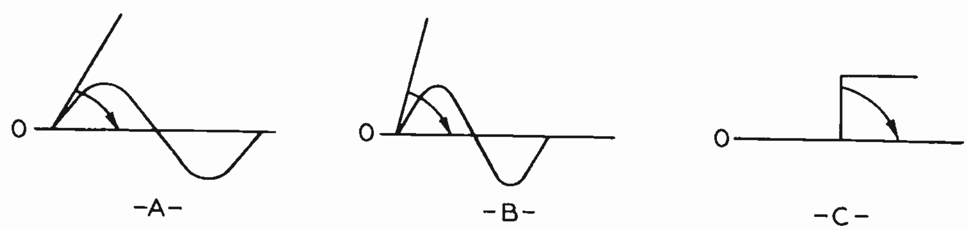


Fig. 4

Note (a) and (b) in Fig. 4. They demonstrate that the higher the frequency, the steeper the rise of the first part of the waveform or "wavefront", as it is known. Now, do not overlook the fact that the closing of a switch results in a "wavefront" too (c). Its rise is even steeper than those of (a) and (b), consequently, the reactance offered by the condenser is very low, practically zero, and there is no voltage lost here. In other words, any way you look at it, the voltage change across the capacitor must be zero at the first instant. This brings forth a very important principle:

The voltage across a capacitor can never change instantaneously.

KIRCHOFF'S LAW: Kirchoff's Law is employed here to show that the change of voltage across R at the first instant is equal to the change of applied voltage, since:

$$\Delta E_{applied} = \Delta E_R + \Delta E_c \text{ (Fig. 3) or}$$

$$\Delta E_R - \Delta E_{applied} = \Delta E_c \text{ and therefore}$$

$$\Delta E_R = \Delta E_{applied} + 0 \text{ or}$$

$$\Delta E_R = \Delta E_{applied}$$

This brings forth a second important principle: The voltage across a resistor can always follow the applied change of voltage instantaneously.

OHM'S LAW: Ohm's law states that: $I = \frac{E}{R}$

Since E_R is maximum at the first instant, then the maximum current must be flowing through R at this instant.

SERIES LAW: The series law is useful mainly to emphasize that the relative positions of R and C in the circuit have no affect on results obtained across any one component.

SWITCH STILL CLOSED (LATER TIME). -- Observe Fig. 3 As time passes, the positive potential applied to the upper plate of C attracts electrons to the lower plate, accumulating a charge (Q) and a resulting E_c. This E_c can be considered as a difference of potential caused by a deficiency of electrons on the upper plate and a surplus of electrons on the lower plate of the capacitor. It has been shown previously that maximum current flows through R at the first instant a voltage is applied. For this reason the capacitor (which is applied with electrons by the current through R) starts to build up its charge at a maximum rate as the charge cycle begins. However, the rate at which E_c rises cannot remain at its initial value. This fact might be more easily understood if the uncharged capacitor were compared to a container which has been evacuated. The instant that a valve is opened the inrushing air would be comparable to the instant of closure of switch X (Fig. 1). Since the vacuum represents an almost complete lack of gas atoms of any kind, there would be the most possible room for atoms (or molecules) to rush in at the first instant. Similarly, there would be room for the most electrons to rush onto one of the capacitor plates. As time passed, however, the demand for gas atoms would lessen, since the available space, or capacity, within the container would diminish. Likewise, the attraction for electrons to the capacitor plate would decrease with the passage of each successive unit of time. Of course, as previously mentioned, electron flow would cease when the capacitor potential became equal to that of the battery. This is comparable to the fact that air would cease rushing into the container when inside pressure equaled outside pressure.

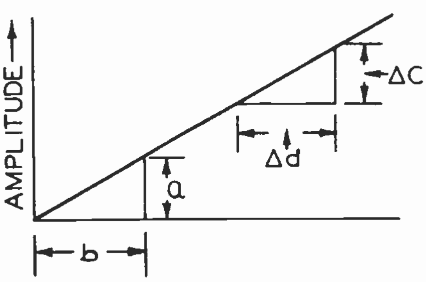


Fig. 5

If the capacitor continued to acquire electrons at the maximum rate realized at the first instant, the voltage would rise in a constant or linear manner. From the study of graph, we know that a linear rate of change is represented by a "curve" which is really a straight line. This is shown in Fig. 5.

This curve shows that the number of electrons per unit time $\frac{c}{d}$ at any point along the time base is exactly equal to the number of electrons per unit time at the first instant $\frac{a}{b}$.

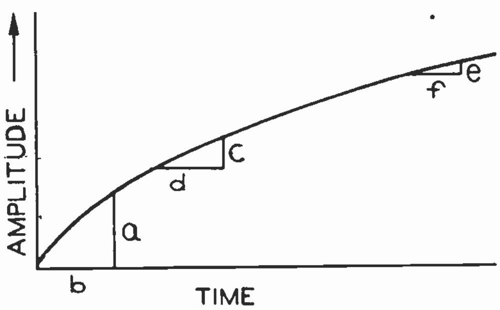


Fig. 6

The rate of change of the capacitor voltage (and charging current) however, has been shown to be steadily decreasing. A graph showing a continual change in the rate of change could not be constructed with a straight line. Rather, it would appear as in Fig. 6.

Note that $\frac{c}{d}$ (rate of change) is smaller than $\frac{a}{b}$.

Still later, $\frac{e}{f}$ is smaller than $\frac{c}{d}$. Complete mathematical analysis of this curve would require differential equations. With the aid of these equations it can be shown that the rate of change is that of a standard and well-known mathematical "progression". This progression is known as an "exponential" rate of change. The curve shown in Fig. 6, therefore is an exponential curve and represents the rate of change of a capacitor. Incidentally, it is sometimes referred to as an "asymptotic" curve, this term being synonymous with exponential.

Referring to Fig. 3 once more, note that E_c - E_R must equal $E_{applied}$ at any instant, in order to satisfy Kirchoff's Law. Surely then, if E_c increases at an exponential rate, E_R must decrease at exactly the same rate, so that the sum of the two voltages will always be equal to $E_{applied}$.

These facts establish a fundamental and important statement:

It is a hard and fast rule that an instantaneous change in applied voltage level is followed by changes across R and C which are exponential.

Before using actual values to illustrate the charging action it will be necessary to describe the time constant which is the key to R-C circuit analysis.

DEFINITION: The R-C time constant is the time in seconds required for the voltage across the resistor of a series R-C circuit to change 63 per cent.

This definition takes into account the possiblity that the capacitor voltage might be something other than zero at the start of a charge or discharge period.

The R-C time constant is the product of the total circuit resistance in ohms and the capacity in farads. It will be immediately apparent that the product in megohms and microfarads will give the same answer and is more practical and convenient. In a subsequent study of the "steady state" condition, the time constant will be useful in determining whether or not the waveform of the output voltage will be altered (and, if so, in what manner.)

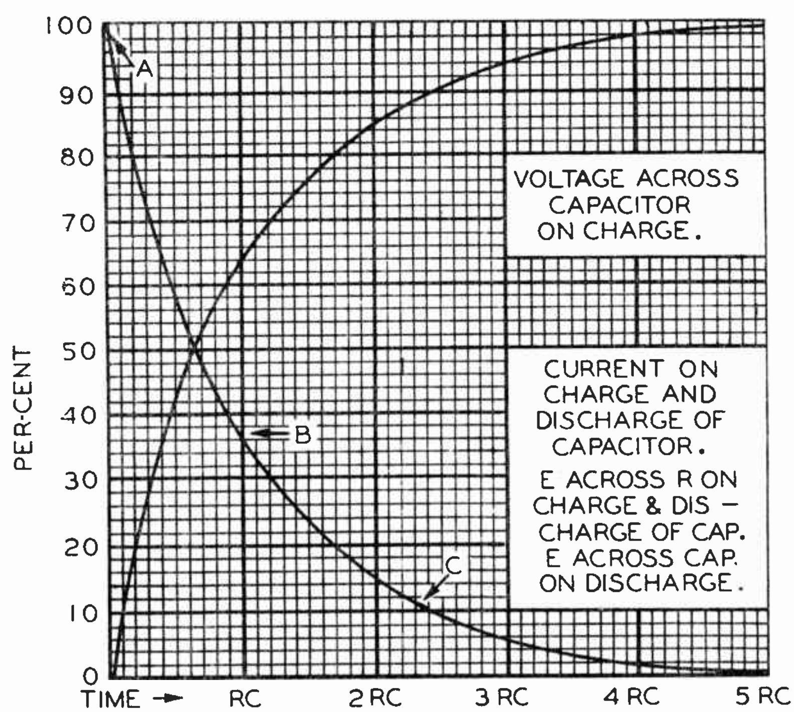


Fig. 7

Observe Fig. 7. This chart is a graph of per cent change (of voltage or current across R or C) versus time (in units of the R-C product or "time constant").

All the voltage variations throughout the circuit are combined in Fig. 7. Study them carefully because they contain the key to the operation of this R-C network and follow the variations in current and voltage throughout the circuit.

Refering to Fig. 8, we will use the curve which indicates the rise in charge across the condenser. At the first instant, there is no voltage across the condenser, just as we expected. The next step, let us determine the time constant of the circuit. Since R is 1 megohm and C is 1 microfarad, together they give an answer of 1 second. Therefore, according to the previous definition, 1 second is the time in which the voltage across R will change 63 percent or to 37 percent of the voltage which appeared across R at the first instant. Take a look at point B in Fig. 7. Note the intersection of the downward sweeping curve and a line perpendicular to R-C (an elapsed time equal to R x C).

Project this point to the percentage axis on the left and find it to be approximately 37 percent. In other words, the voltage across R is 37 percent of the voltage across R at the first instant or, in this case, the voltage across R at the end of RC time is 37 volts.

Since the applied voltage change was 100 volts, then, in order to satisfy Kirchoff's Law, the capacitor voltage at the end of a time equal to R-C must be 100-37 or 63 volts. This is also substantiated by the R-C chart. The intersection of the line perpendicular to R-C and the upward sweeping curve shows 63 percent when projected to the left.

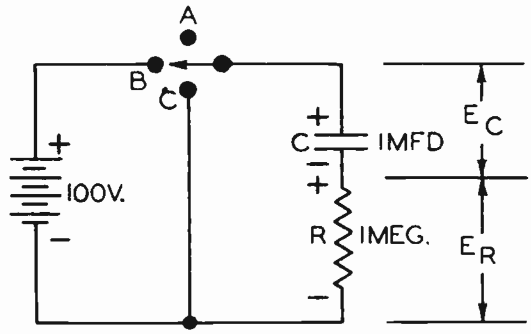


Fig. 8

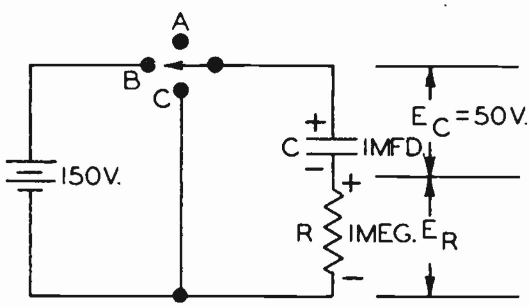


Fig. 9

Next, Fig. 7 shows the voltage existing across R and C at still later times. It can be seen that the capacitor will eventually acquire a charge nearly equal to the applied change of voltage. Theoretically, E_c can never equal $E_{applied}$ but, from a practical viewpoint, E_c will just about equal $E_{applied}$ in a time equal to five times the product of R and C (in 5 seconds). This is shown quite clearly on the RC chart.

Thus far, an examination of the charging action has been conducted from a time when the switch has been open for such a long time that the voltages across R and C were necessarily zero. However, in many cases, the charging action may start when a certain potential already exists across the capacitor. This may seem at first, to complicate the issue; actually, the solution of such a problem is nearly as simple as that of the problem previously discussed. There remains no better proof of that statement than to set up a problem and solve it.

In Fig. 9, the switch has been in position A for some time. Due to a previous application of voltage change, the capacitor has some voltage across it. Of course, this charge is gradually leaking off the capacitor. It is a high quality capacitor, though, so the leakage is light. However, the switch is set to point B at this instant, while the capacitor still has 50 volts (of the polarity shown) across it.

The first problem is to ascertain the values of voltage appearing across R and C at this instant. One single idea will provide a positive solution: Whenever a difference of potential exists across a capacitor, it may be treated as another battery. . . a battery which can be charged or discharged rapidly but, at any one instant, a battery in the circuit, nevertheless. Therefore, if a 50 volt potential appears across C at the first instant of moving the switch to position B, the net voltage change impressed across R is the algebriac sum of 150 volts and 50 volts, of the polarity shown. Fig. 9 shows E_b and E_c to be opposite in polarity, which means that the voltage across R is 100 volts at this instant. The rest of the problem requires absolutely nothing new for its solution. At the end of 1 second (RC time) the voltage has changed 63 per cent or to 37 per cent of the original change across R (which netted 100 volts) so, the voltage across R at the end of one second is 37 volts. Kirchoff's Law reveals 150-37 or 113 volts across C at this same time. If the switch has remained in position B for 3 times RC, or 3 seconds, the RC chart shows that E_R would be 5 per cent of the original E_R (100 volts), or 5 volts. Kirchoff's Law would now give 150-5 or 145 volts as the value of E_c.

Summarizing the Charging Action:

a. The change of voltage across R can always follow the applied change instantaneously.

b. The change of voltage across C can never follow the applied change instantaneously.

c. At the end of a time equal to the product of R and C, the voltage across R will change 63%, or to 37% of its original value.

d. At the end of RC time, the voltage across C is equal to the applied voltage change minus E_R.

e. Regardless of the capacitor voltage at the instant of the charge cycle, the voltage across R will change 63 percent of the original voltage change across R in RC time. The only difference lies in the fact that the original change across R is the algebraic sum of $E_{applied}$ and E_c, when there is voltage across the capacitor at the start of the charge cycle.

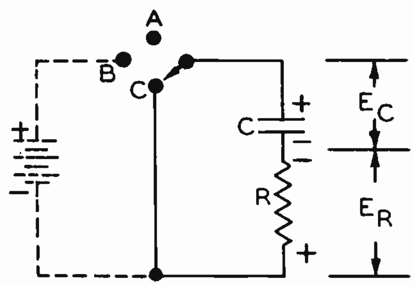


Fig. 10

DISCHARGING ACTION

Thus far, a voltage change has been applied to R and C by moving the switch to position B. As long as the switch remains in this position the charging action will continue. Now however, the discharging action is to be studied.

(1) 1st Instant (position C):

If the switch is moved to position C (Fig. 10), another change of voltage is immediately impressed upon R. This change is furnished by the only "battery" which remains in the circuit, the capacitor. It is plain to see that one "battery" and one resistor are all that now make up the circuit. Since E_R can follow the applied change of voltage instantaneously and E_c cannot, the E_R must equal E_c at the first instant the switch is moved to position C. Furthermore, in order to meet Kirchoff's Law (that the algebraic sum of the voltage drops around the circuit be zero) E_R must be opposite in polarity to E_c. A comparison of Fig. 10 with Fig. 9 will show that E_R is now negative at the top, where it was positive during the charge cycle.

It was comparatively simple to establish the amplitude and polarity of the voltages E_R and E_c at the first instant of the discharge cycle, but what happens from this time on is just as simple. As long as the switch is in position C, E_c equals E_R at any time.. Therefore, it is only necessary to know how E_R changes and E_c must be equal but opposite in polarity at any time during discharge. How much does E_R change? In a time equal to R - C E_R changes 63 percent or to 37 percent of the original change, the change which took place the instant the switch moved to position C).

Problem: Assume E_c to be 50 volts (of the polarity shown in Fig. 11) at the start. A change of 180 volts is applied to a series RC circuit consisting of R = .99 megohms and C = 1 microfarad. After the switch has been in position B for 2 seconds it is moved to position C instanttaneously. What is the value of E_c three seconds after the switch is moved to position C?

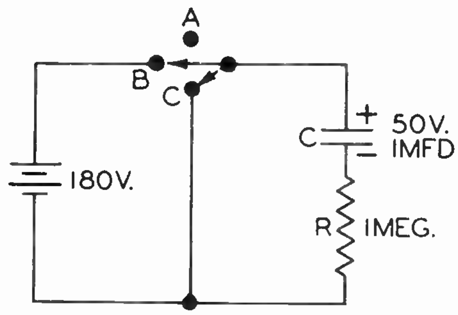


Fig. 11

Solution:
(a) The net voltage change applied to R at the first instant is the algebraic sum of the two "battery" voltages. Since $E_{applied}$ and E_c are opposite in polarity, the net change is +180 - 50 or +130 volts.

(b) Since R can follow this net change instantaneously, then E_R is +130 volts at the first instant.

(c) The RC chart (Fig. 7) shows that E_R at the end of 2 sec., will change to approximately 13.6 percent of the original 130 volts, or .136 x 130 = 17.7 volts.

Note: This can be solved without the aid of the RC chart, if necessary. The time from 1 RC to 2 RC is the same as that from the first instant to 1 RC. Therefore, the voltage at 2 RC is 37 percent of the voltage at 1 RC. It can readily be seen that the voltage at 2 RC is 37 percent at 1 RC. 37 percent of 37 percent is 13.6 percent. This process can be carried out for as many multiples of RC time as need be. As an example, the voltage of 3 RC is 37 percent of the 13.6 percent at 2 RC, or approximately 5 percent. A glance at the RC chart will confirm this fact.

(d) If, at the end of 2 RC time, E_R is 17.7 volts, then Kirchoff says that $E_c = E_{applied}$ minus E_R = 180 - 17.7 = 162.3 volts across the capacitor at the end of 2 RC time.

(e) Now, the switch moves instantaneously to position C. E_c cannot change at the first instant, so E_R must be equal and opposite in polarity at this time. E_R therefore, is -162.3 volts at the instant the switch moves into position C.

(f) Using either the RC chart or the method described in step (c), it is found that in 3 RC time E_R changes to 5 percent of the original E_R (which was 162.3 volts, produced by switching to position C) or to approximately 8 volts.

(g) The problem asks for the value of E_c at this time. Of course, as long as the switch is in position C, E_c must equal E (Kirchoff) so E_c= 8 volts (answer)

STEADY STATE CONDITION

The previous discussion of the "Transient Condition" served to establish some fundamentals of RC circuits which may be applied to the move common "steady state condition".

DEFINITION: Steady state condition refers to the state of the circuit when the applied voltage consists of a periodic repetition of both polarity and amplitude of change, with respect to time.

This change may be sinusoidal or may take any of an infinite number of possible complex shapes. Common examples of the complex form include square, rectangular, sawtooth and triangular waves.

The object at this point is to apply a "steady state" waveform to a series RC circuit and determine the resulting output waveform (the voltage change across the resistor). If, in the previous problems, you had moved the switch from B to C and back at equally spaced intervals, you would have been applying a "steady state" waveform to the RC circuit. Moving the switch to B would produce an instantaneous rise to some positive value. As long as the switch remained at B the applied voltage would have remained constant at this positive value. Moving switch to position C would have caused the applied voltage to drop instantly to zero, where it would have remained constant until the switch again moved to B. If this sequence of events had occurred at regular intervals, the "waveform" of the applied voltage would actually be that of a square wave. (Fig. 12)

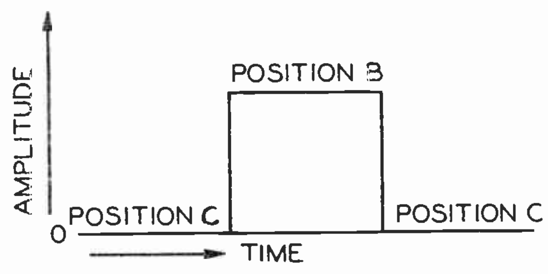


Fig. 12

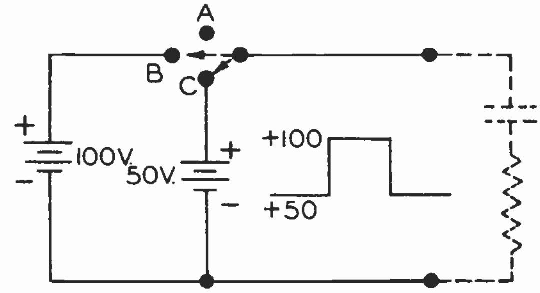


Fig. 13

It will be seen later in actual practice that this square wave is produced by a vacuum tube stage. The square wave output will be the result of an instantaneous change in plate voltage level. Now, in most cases, the plate voltage of a vacuum tube amplifier does not drop to zero at any time. Therefore, a square wave output from such a stage would have to be the result of two different levels of positive voltage. This sort of waveform could be simply shown at this time with two batteries, as in Fig. 13 (Remember that the switch is alternating regularly between B and C.).

The amazing result of applying any steady state waveform to a series RC circuit is this: No matter what the polarity of the applied waveform (i.e. all positive, all negative, or part positive and part negative) if the change in level of the applied voltage is the same, then the output voltage across R will be exactly the same in any case. Detailed development and proof follow immediately.

Three representative waveforms, sine, square and sawtooth, are to be applied to the following circuits:

1. T = RC (Intermediate time constant)
Where the product of R and C is equal to the time of one-half cycle.

2. Large time constant
Where the product of R and C is great, compared to the time of one-half cycle.

3. Small time constant
Where the product of R and C is small, compared with the time of one-half cycle.

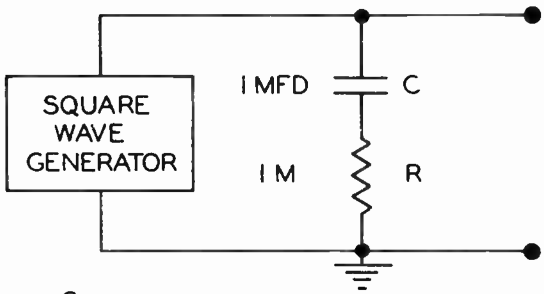


Fig. 14

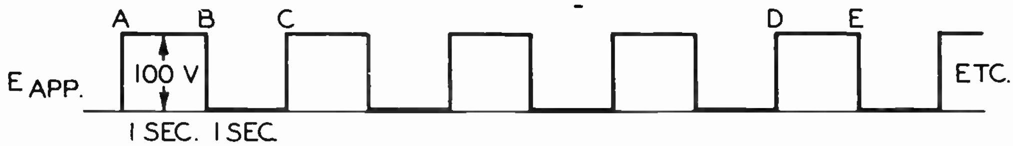


Fig. 15

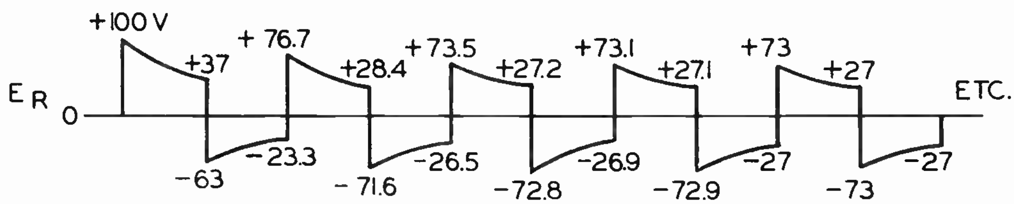


Fig. 16

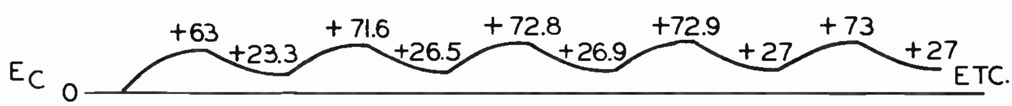


Fig. 17

THE SQUARE WAVE

1. When T = RC:

Figs. 15, 16 and 17 will be used to describe the result of applying a square wave, one-half cycle of which requires one second, to R and C whose product is one.

NOTE: All polarities are with respect to ground.

a. As previously stated, after a given change of applied voltage and an elapsed time equal to the product of R and C, the voltage across R changes 63 percent of the original voltage across R.

b. Note that the applied voltage change is 100 volts at A (Fig. 15) and remains at that value for one second (a time equal to one microfarad x one megohm).

c. The entire applied voltage change appears across R at this first instant (Fig. 16), due of course, to the fact that the resistor voltage can change instantaneously.

d. The voltage across R then changes 63 percent or to +37 volts (a decrease of positive voltage across R) in RC time (1 second).

e. At B (Fig. 15) another voltage change of 100 volts is applied, but in the opposite direction (a "negative-going" voltage).

f. Since R will assume the full change at the first instant, E_R will change 100 volts in a direction opposite to that at A, subtracting from 37 to produce -63 volts.

g. At the end of 1 second the voltage across R will have changed 63 percent from the original -63 volts, decreasing to a less negative value of -23.3 volts.

h- At point C (Fig. 14) a "positive-going" 100 volts change is again applied, changing E_R from -23.3 to +76.7 volts.

i. Notice that if the calculations indicated in Figs. 15, 16 and 17 are completed, it can be seen that the voltage at any given point in the second cycle is slightly different than the voltage at the corresponding point in the first cycle. Likewise, the voltage at said point in the third cycle differs from that in the second cycle etc., but finally, in the fifth cycle (points D and E, Fig. 16), it is seen that the voltage is now the same (at any chosen point) every cycle. This is known as the "steady state". This condition is also referred to as the "state of equilibrium". The larger the product of RC in comparison to the time of the cycle (in other words, the larger the "time constant"), the greater will be the number of cycles required to reach the "steady state".

Additional Notes:

a. Note that a zero reference has not been specified for the applied waveform (Fig. 15). The waveform could have been (1) entirely above zero, (2) entirely below zero, or (3) partially above and partially below the zero level. The result across R (Fig. 16) would be exactly the same in any case.

b. Note that, whenever the applied voltage changed 100 volts instantaneously, the voltage change across R was also 100 volts.

c. The voltage changes across C (Fig. 16) are determined as follows:

(1) On the "change" half cycle E_C is equal at any instant to $E_{applied}$ minus E_R (Kirchoff).

(2) On the "discharge" half cycle E_C is equal at any instant to E_R but opposite in polarity.

2. Large time constant

In applying a square wave to a circuit with a large time constant, use will be made of the same generator employed in the previous problem (remember, it has an output 100 volts amplitude and the time of one-half cycle is 1 second). The only change necessary is in the product of R and C. Either R or C (or both) could have been changed, just so the product could have been changed, just so the product is right. For a given time constant, there is an infinite number of possible combinations of R and C.

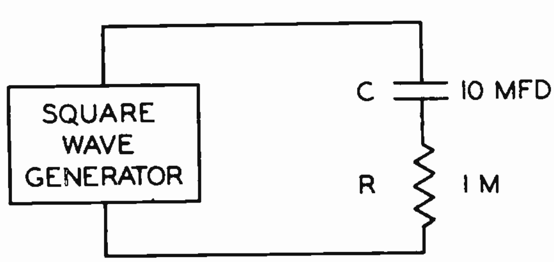


Fig. 18

For a large time constant, the product of R and C is to be ten times the time of one-half cycle of the applied voltage waveform. Therefore, 10 microfarads and 1 megohm will provide a 10 second time constant (Fig, 18).

a. As in the case where T = RC, the voltage across R will equal the applied voltage change at the first instant, A (Fig. 19).

b. The voltage across R would require 10 sec-

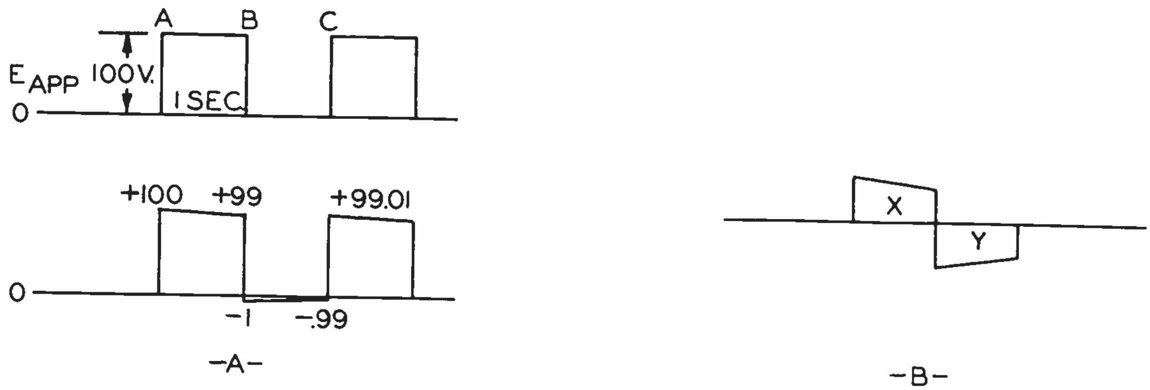


Fig. 19

conds (T = RC) to change to 37 volts, but there is only 1 second between voltage change in the applied waveform----just time enough to decrease about 1 percent (or 1 volt, in this case), dropping down to +99 volts.

c. Then comes the "negative-going" change of 100 volts at B. Again, as in the case where T = RC, E_R will change the full 100 volts, from +99 volts to -1 volt.

d. Once more, E_R has only 1 second in which to change so, due to the large RC product, it can change only 1 percent or from -1 volt to -.99 volt.

e. At C the "positive-going" 100 volt change occurs again, E_R assumes the full 100 volts change, and goes from -.99 to +99.01 volts.

f. This process continues until the steady state is reached and area x is equal to area y (Fig. 19b). A considerable number of cycles must pass before the steady state is realized this time, due to the effect of the large time constant.

g. It is seen that the output waveform (E_R) retains the same essential shape as the applied waveform. However, the output is an ac waveform, regardless of whether the input is ac or pulsating dc.

Summarizing:

The larger the product of R and C, with respect to the time of the applied voltage, the more nearly will the output waveform (E_R) be an exact reproduction of the applied waveform.

3. Small time constant.

Once more, the same generator, putting out the same frequency is put into service. This time its output will be applied to a RC product of ($.1 \times 10^6$) x ($.1 \times 10^{-6}$) or .01 secs. This means that E_R can change 63 percent in .01 seconds (T = RC).......or 99 percent in .05 seconds (5RC).

a. At the first instant, A, E naturally assumes the entire change (since C looks like a short circuit to this high frequency wavefromt). Therefore, E_R at the first instant is 100 volts.

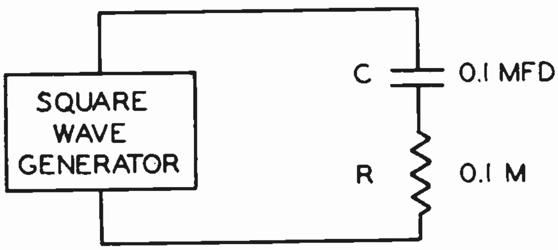


Fig. 20

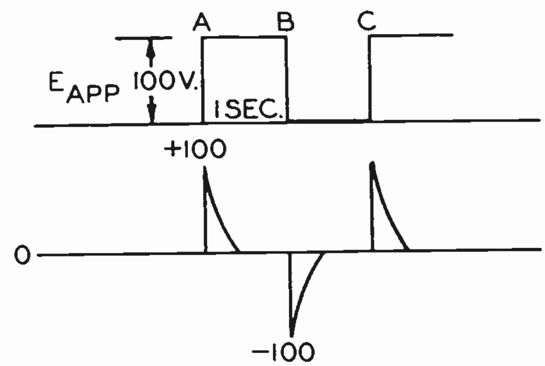


Fig. 21

b. Since E changes 90 percent in .05 seconds it drops from 100 to practically zero in .05 of the time between A and B.

c. At B there is the "negative-going" change or 100 volts, which E_R, of course, will assume at the first instant.

d. Again, in .05 seconds E_R changes 99 percent or to practically zero.

e. The steady state is reached almost immediately.

This type of circuit is known as a "differentiating circuit." The differentiating circuit will be of extreme importance in television. Let us therefore examine it more critically.

First of all, the differentiating circuit will be defined. This definition will permit prediction of the shape of the output waveform of said circuit, regardless of the shape of the input waveform.

DEFINITION: A differentiating circuit is a series RC circuit with the output voltage taken from across the resistor, the amplitude of which tends to be directly proportional to the rate of change of the applied voltage.

An infinitely small time constant would produce an output that is truly in direct proportion to the rate of change of the input. The RC product of the average differentiating circuit is not small enough to achieve this edeal relationship, however. Still the input of a differentiator can be made to resemble the ideal waveform closely enough for all practical purposes. Try it out on the square wave. The rate of change of the applied wave is seen to be maximum at A (Fig. 21), and so is the amplitude of E_R (output voltage). Next, the rate of change of $E_{applied}$ from A to B is zero and nearly so is the amplitude of E_R. Then at B the rate of change of $E_{applied}$ is maximum in the opposite direction, so is the amplitude of E_R. Any waveform will respond to this analysis. This will be proven as the discussion progresses.

THE SAWTOOTH WAVE

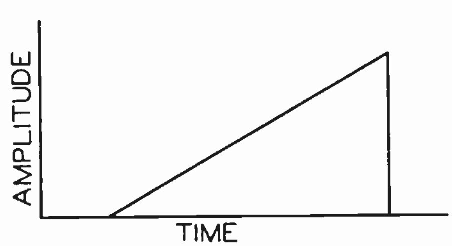


Fig. 22

The ideal sawtooth waveform is that of a voltage which rises linearly or at a constant rate of change to its maximum value, dropping instantaneously to its minimum value. This ideal waveform is shown in Fig. 22.

In actual practice, however, the common sawtooth generator does not put out such a perfect waveform.

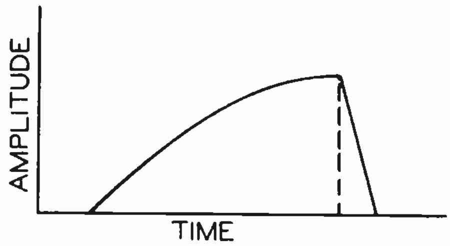


Fig. 23

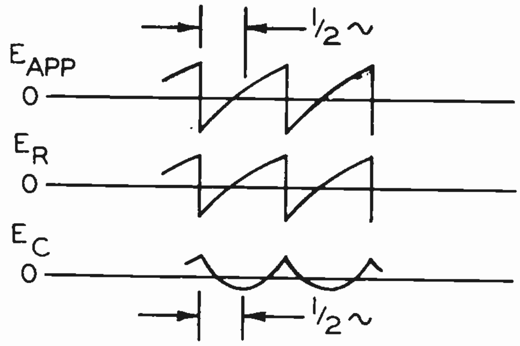


Fig. 24

Rather, there is some nonlinearity in its rise and it requires some time to drop from its maximum to its minimum value. This is shown in Fig. 23.

In most television circuits, the sawtooth wave that is obtained is a compromise between Fig. 22 and 23. A complete treatment of practical sawtooth generators will be given in another lesson.

1. T = RC

Consider the application of a sawtooth wave to a series RC circuit, the RC product of which is equal to the time of one-half cycle of the sawtooth wave. Under the above stated conditions the output waveform undergoes some change in shape, but not as much as in the case of the square wave. This is due to the comparatively slow rise of applied voltage which the capacitor can nearly follow when T ≈ RC.

Since three rates of change take place simultaneously ($E_{applied}$, E_c, and E_R), actual calculations are too complex for this discussion. However, true waveforms taken from the oscilloscope and drawn to scale are shown in Fig. 24.

Note that once more the output waveform (E_R) has an area above the zero level equal to the area below.

2. Large Time Constant

A sawtooth waveform is applied to a series RC network (1) to change it from pulsating dc to an ac waveform and (2) to isolate the sawtooth generator from the next stage. If the generator is developing a sawtooth rise of voltage from 16 to +116 volts; the entire waveform is positive (pulsating dc). Application of this waveform to a long time constant RC circuit will produce an output which is essentially a duplicate in shape, but which is both negative and positive with respect to zero. Fig. 25 shows this condition.

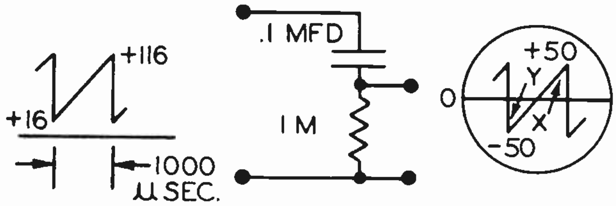


Fig. 25

(As in previous examples, area x is equal to area y).

A sawtooth voltage rises in a positive direction at a rate which is very slow compared to the sudden steep rise of a square wave. When this type of waveform is applied to a small time constant circuit the capacitor can, therefore, charge up almost as rapidly as the applied voltage rise. Compliance with Kirchoff's Law than dictates

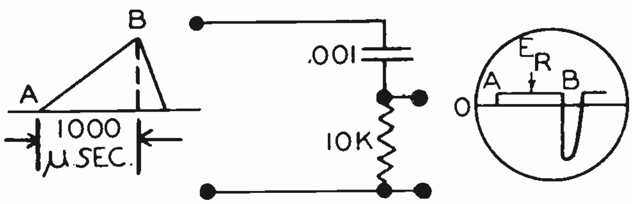


Fig. 26

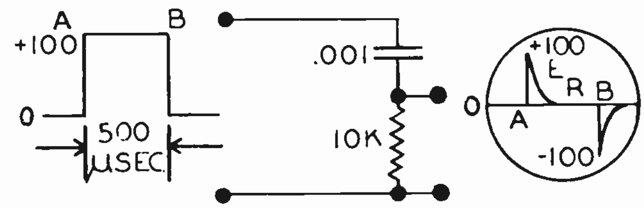


Fig. 27

the fact that E_R will rise but very little from point A to point B in Fig. 26.

However, when the applied voltage has risen to point B, it then drops in a negative direction almost instantaneously, just like the trailing edge of a square wave (point B, Fig. 26). As a result, the capacitor cannot follow this change and the total change of applied voltage appears across R for an instant producing a sharp negative pulse. In other words, what happens at B in Fig. 26 is almost exactly the same as what happens at B in Fig. 27.

Here again, the definition of the differentiating circuit holds true. The rate of change of $E_{applied}$ from A to B is relatively small and constant. The rate of change of $E_{applied}$ at B is maximum, so is E_R.

THE SINE WAVE IN SERIES RC CIRCUITS

This part of the study of series RC circuits has been covered fairly completely in fundamental ac theory, so that it should be a rather simple matter to review that work. Toward that end, the following brief treatment is presented for the purpose of review.

The sine wave will be applied to the two opposite types of series RC circuits, i.e. 1. the large time constant and 2. the small time constant (differentiating circuit.)

1. Large time constant

A large time constant bears the same relation to a sine wave as it does to a square wave. In other words, the product of R and C is large compared to the time of one-half cycle.

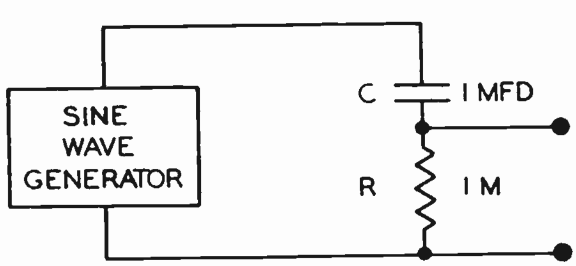


Fig. 28

Fig. 28 shows a 60 cycle sine wave applied to a series RC circuit in which R is 1 microfarad and C is 1 megohm.

To find the time of one-half cycle, it is necessary to recall that the time of one cycle is the reciprocal of the frequency.

$$T = \frac{1}{f} = .016667 \text{ seconds.}$$

When the time is a small fraction of a second (as is usually the case in radio) it is common practice to use the microsecond as the basic unit.

Hence, the time of one 60 cycle waveform is 16,667 micro seconds; the time of one-half cycle then is 8,333 microseconds.

Note: Since the product of R and C is 1 second or 1,000,000 microseconds, this time is (to put it mildly) great, compared to 8,333 microseconds.

A sine wave applied to a series RC circuit will undergo no change in waveform, no matter what the time constant may be. However, the amplitude of E_R and its phase relationship to $E_{applied}$ are definitely dependent upon the time constant. These results can be properly evaluated with the application of a little of the simplest ac mathematics.

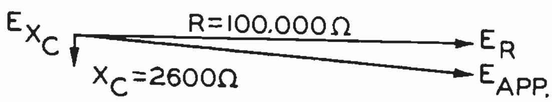


Fig. 29

First, find the reactance of C to 60 cycles $(\frac{1}{2\pi fc})$. You find X_c at 60 cycles to be roughly 2600 ohms. Now represent E_R, E_{xc} and $E_{applied}$ by the appropriate vectors, as in Fig. 29.

It can be seen that the output voltage across R is nearly equal in amplitude to $E_{applied}$ and E_R is practically zero, in the case of the large time constant.

It is interesting to note that R and C can be any combination of values. As long as the RC product is the same, the amplitude and phase relationship will be the same.

2. Small time constant.

For this case consider that the same 60 cycle sine wave (Fig. 28) is being applied to a series RC circuit in which R is 10,000 ohms and C is .01 microfarads (See Fig. 30).

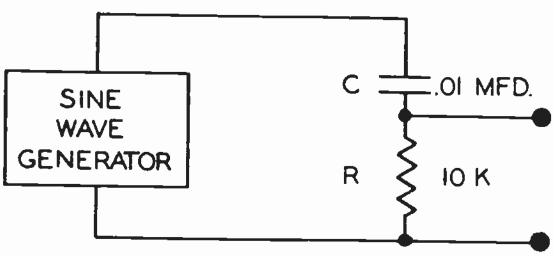


Fig. 30

The RC product this time is .01 x .01 = .0001 or 100 microseconds, quite small compared with 8,333 microseconds. Again find the resistance of C to 60 cycles. This time it is 260,000 ohms. Now construct another set of simple vectors to show the phase relationships. It appears that the output voltage, E_R leads the applied voltage $E_{applied}$ by nearly 90^o and has an amplitude that is very small, compared with $E_{applied}$.

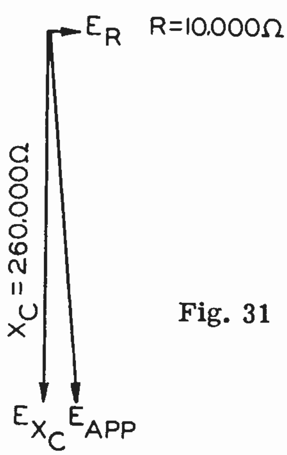


Fig. 31

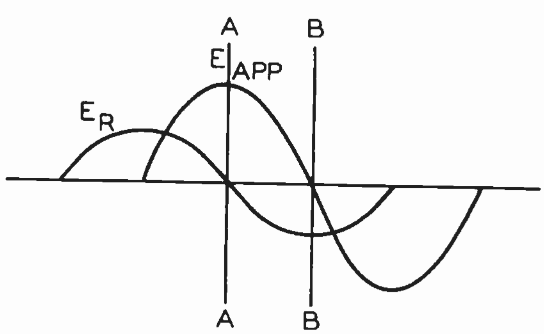


Fig. 32

Does the definition of the differentiating circuit apply to the sine wave? It most certainly does. Take a look at the waveforms of $E_{applied}$ and E_R superimposed, one upon the other in Fig. 32. It can be seen that the rate of change of $E_{applied}$ at point A is zero; so is the amplitude of E_R. At point B the rate of change of $E_{applied}$ is maximum; so is the amplitude of E_R.

SUMMARY:

1. A sine wave undergoes no change in wave form when passed through a series RC circuit, no matter how small the time constant.

2. A sine wave applied to a series RC circuit results in an output voltage across the resistor which is reduced in amplitude and leads $E_{applied}$ in phase by an amount dependent upon the time constant. The smaller the time constant, the smaller E_R and the greater the phase shift will be.

3. A very large time constant results in practically zero phase shift and almost no reduction of amplitude.

4. A very small time constant results in a nearly 90° leading phase angle and nearly zero amplitude of output.

INTERGRATING CIRCUITS

Since the integrating circuit is employed in television circuits, a brief discussion of its main features is included here.

The integrator circuit, differs from the differentiatior circuit in that the output voltage is taken from across the capacitor. The waveform of the output bears a definite relationship to the input waveform which may be easily predicted with the aid of the following definition:

DEFINITION: An integrating circuit is a series RC circuit in which the amplitude of output voltage tends to be directly proportional to the amplitude of the input voltage. Again as in the case of the differentiator circuit, the output is directly proportional only when the time constant is infinitely small; however, when the time constant is reasonably small, the definition is a workable tool in the practical sense. Fig. 33 shows the waveforms resulting from the application of a triangular wave to a series RC circuit.

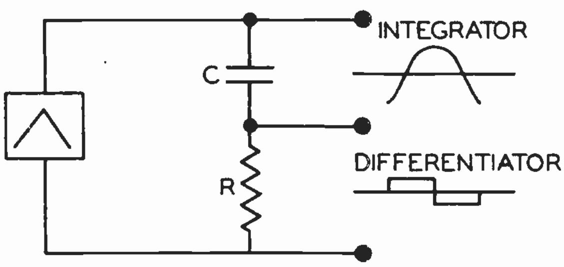


Fig. 33

Note that both the integrator and the differentiator outputs are shown and that each waveform meets the requirements of the definition of that particular type circuit.

The definition of the integrating circuit may also be applied in predicting the output waveform (across C) resulting from application of square, sawtooth, and other complex waveforms. For example, apply a 100 cycle square wave to a series RC circuit, in which R is 10,000 ohms and C is .001 (Fig. 34).

1. Since $t = \frac{1}{f}$, the time of one cycle equals $\frac{1}{1000}$ = .001 or 1000 microseconds. The time of 1/2 cycle, then, is 500 micro-seconds

2. The RC product is .01 megohms x .001 microfarads = .00001 or 10 microseconds.

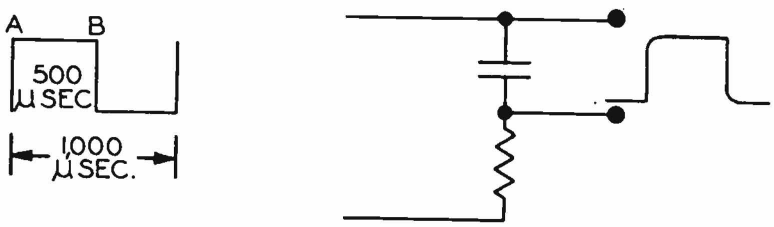


Fig. 34

3. Since the time constant is 10 microseconds, the capacitor will charge to practically the full amount of applied voltage change in 5RC or 50 microseconds -- But, 50 microseconds is only 1/10 of 1/2 cycle along the time base. Therefore, for all practical purposes, the output voltage (E_C) rises instantly and, thus far, may be considered a replica of the applied waveform.

4. From point A to point B, $E_{applied}$ does not change in amplitude. Therefore, since there is no reason for C to charge or discharge, E_C does not change either.

5. At B, the applied voltage goes sharpy in a negative direction, beginning the discharge cycle.

6. The small time constant will, of course, allow C to discharge just as rapidly as it was able to charge. The output voltage (E_C), then, will change in the negative direction just as much and almost as rapidly as the applied voltage changes.

7. It should be apparent, without further development that the waveform across C is a reasonable facsimile of $E_{applied}$ -- and that the definition of the integrating circuit holds true. As a second example, apply a sawtooth wave of the same frequency as that above to the same circuit as shown in Fig. 35.

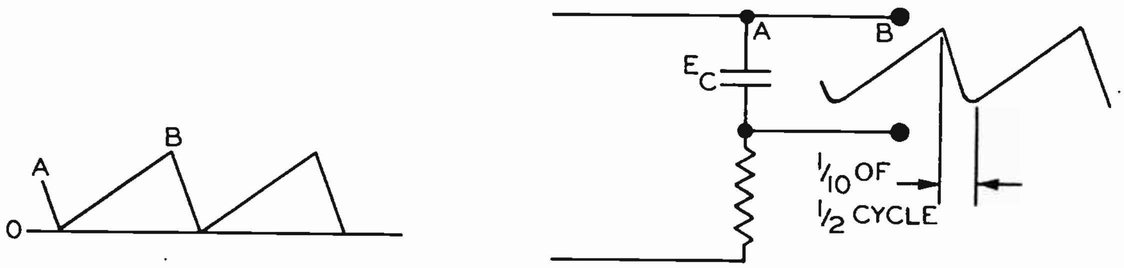


Fig. 35

1. If the capacitor were able to follow the sudden change, at A, in Fig. 34, then common sense suggests that it can follow the slow change from A to B in Fig. 35 very well.

2. At B, the applied waveform looks just like a square wave; E_C is able to follow the change in $E_{applied}$ 1/10 of 1/2 cycle later, just as it did when the square wave was applied.

3. Observe then, that the output is once more a reasonable facsimile of $E_{applied}$ and follows the definition of the integrating circuit.

CHAPTER VII

TIME BASES FOR CATHODE RAY TUBES

In previous lessons we discussed the methods used to focus the electrons in the cathode-ray tube into a small well-defined point of light on the screen. We also examined the advantages and disadvantages of using magnets or plates inside the tube to sweep the electron beam up and down, back and forth over the fluorescent screen. We have left to this assignment, however the discussion of the various circuits and tubes which are used to actuate these deflector plates or coils. As we shall see later in the text, it is vital that the deflection of the spot across the screen be linear with respect to time. That is, that if the spot takes 100th of a second to go one cm., at one portion of the screen, then it should continue to travel at this velocity in other portions of the screen. This linearity of deflection with respect to time is essential for distortionless and uniformly bright picture rasters. In addition to this, the deflections of the beam at the receiver should occur at the same rate as the deflections at the transmitter. Thus, the "sweep circuits" as they are called, must run isochronously. However, when the scanning point as at one position at the transmitter, the scanning point at the receiver must be at a corresponding position. Thus, not only must the sweep circuits be isochronous, but they must be synchronous if pictures are to be reproduced correctly. The circuit values of the sweep circuits at the receiver are arranged so that the latter produces isochronous deflections. But a special type of signal mixed in with the picture signal is relied upon to maintain synchronism. Logically they are called "synchronizing signals".

The proper raster can be produced by two sweep circuits which apply signals to their respective deflection means which are at right angles to one another and to the cathode-ray beam. As mentioned before, there are two fundamental methods of deflecting the cathode-ray beam. The first of these methods is called electrostatic deflection, and it consists of applying a potential difference between two metal plates placed near the beam. The two plates may be compared to a condenser of very small capacity. They are placed parallel to one another and they produce deflections of the beam toward the more positive plate. The other method of deflection is called electromagnetic deflection, and it employs two solenoids located one on either side of the tube neck. The deflection of the cathode ray beam occurs according to the right-hand rule, (motor rule). Thus, if the first finger points in the direction of the field (toward the south pole) and the second finger points in the direction of the cathode ray beam, then the deflection will take place at right angles to both these directions in the direction that the thumb indicates. Irrespective of the type of deflection used, the linear sweep is the same. In the case of the electrostatic deflection, a voltage amplifier must be used to produce the 500 to 1,000 volt potential necessary while in the case of electromagnetic deflection, current amplification must be used to supply the necessary magnetic flux.

Thousands of different patterns can be easily formed on the fluorescent screen by the application of various waveforms to the deflection plate. The trace shown not only depends upon the frequency relationship between the two voltages or currents, but also upon their amplitudes and the phase relationship existing between them. For instance, if two sine wave voltages of the same amplitude and frequency are applied to the deflecting plates of a cathode ray tube, and they are in the same phase (or the phase difference between them is zero degrees), then a straight line inclined at an angle of 45° will be shown on the screen. If the voltages are slowly forced out of step with one another, the straight line will broaden out into an ellipse until the point when the voltages become 90° out of phase when the ellipse becomes a circle. On increasing the phase difference, an ellipse will again be formed though it will tilt in the opposite direction. Finally, when the phase difference becomes 180° a line will once more be formed, but inclined at an angle of 135°. This will be made clear by reference to the diagrams in Fig. 3. If one of these voltages is disconnected, leaving but one set of deflector plates, then a single line trace will be produced.

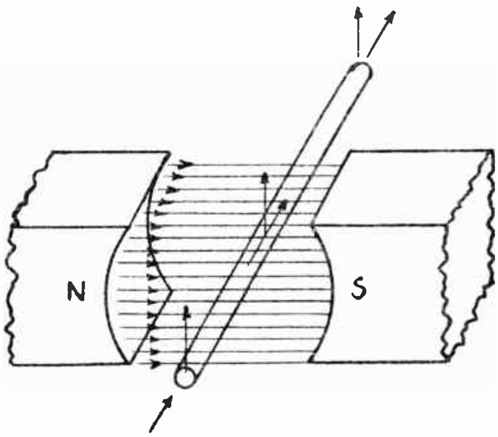


Fig. 1. A conductor passing electrons moves through a magnetic field in accordance with the motor rule as shown

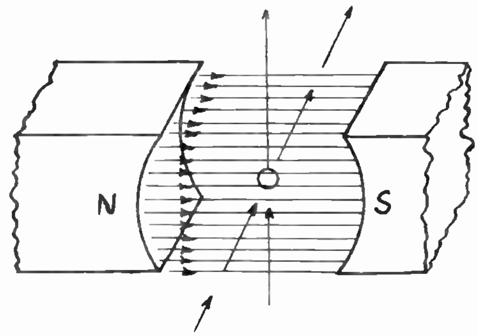


Fig. 2. An electron moves through the magnetic field after the manner of a conductor passing a stream of electrons or an electric current.

If this line is observed closely, the portions nearest the ends will be seen to be much brighter than the portions in the center of the line. This is because the beam travels faster in the center than at the ends of the sweep. This is characteristic of many types of deflection impuses, a sine wave being one of them. Such a deflection would be obviously unsuitable for television purposes. If the trace could be made to travel at the same rate at the center as at the outer portions so that a constant velocity of the spot across the screen would be maintained, then obviously, this would provide the solution for television purposes. However, we have another requirement. When a sine wave is used for deflection purposes, a deflection takes place in both directions so that the trace of the beam in one direction is as clearly evident as the trace in the other direction. That is, the

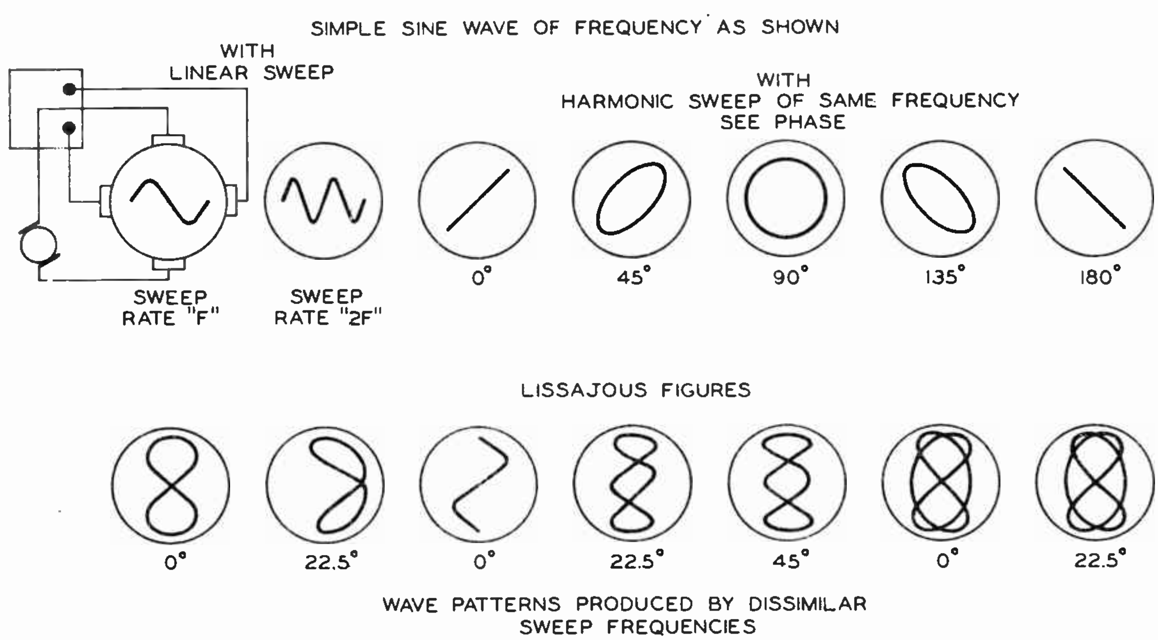


Fig. 3.

beam is swept back and forth in the same order of velocities. It has been decided, however, that the beam should travel across the screen, vanish and reappear at the other side, so that the scanning motion shall always take place in the same direction. The time that the beam does not appear on the screen is called the retrace or fly back time, and this period is utilized for the synchronizing signals. Now it is apparent that we must have available a current or voltage which increases uniformly with time to a certain value, and then drops very quickly to zero. A wave possessing this characteristic is called a saw-tooth wave and the production of this waveform and its maintenance in subsequent amplifiers is one of the most important problems in the design of cathode-ray receivers.

There is an almost infinite number of circuits that will produce saw-tooth waveforms. One of the simplest of these circuits is composed of a regular sine wave oscillator and a chopper which suppresses all but the part of the wave occuring within 30^o of the axis. This portion of the sine wave is approximately linear, so that a crude form of saw-tooth wave is produced.

In the last few years two main types of saw-tooth wave generators have evolved. One of these uses a gas relay tube, while the other is a high vacuum tube circuit. The former type of circuit is the simplest to deal with, and it once enjoyed great popularity. It does, however have disadvantages which are due to the variability of the characteristics of the gas tube. Gas tubes, it seems, cannot be manufactured with perfectly uniform characteristics like the ordinary vacuum tube. The amount of gas in each tube varies, also the temperature at which the tube is operated determines the pressure of the gas. We have seen from previous assignments that the striking potential of the potential at which a gas ionizes is dependent upon the pressure of the gas. In sweep circuits the striking potential determines both the amplitude and the frequency of the sweep so that spontaneous changes in its value may serve to cause distortion in the picture raster. For this reason various vacuum tube arrangements are used in all television receivers. However, the gas tubes lend themselves readily for illustrating the development of saw-tooth voltage waves and as such, are quite useful. Once the rise and fall of the wave is thoroughly understood, we will examine the circuits currently employed.

THE NEON-TUBE OSCILLATOR

The simplest type of oscillator which produces a wave form approximately saw-tooth in shape is known as the relaxation oscillator. It depends upon the slow charging of a condenser through a resistance and its rapid discharge through a simple neon tube. The condenser is connected to a source of DC through a resistor. The glow lamp is connected directly across the condenser. Current begins to flow into the condenser through the resistor, and the latter becomes equal to the striking of the gas within the tube the latter "breaks" down or becomes ionized. Due to the low resistance of the ionized gas, the potential across the condenser drops rapidly. Finally, a point is reached when the potential across the condenser is no longer sufficient to maintain the discharge, so the current through the lamp ceases, and the potential across the condenser begins to rise once more. The voltages at which the lamp strikes and at which the lamp ceases to glow differ by a comparatively large amount, and it is between these two values that the fluctuations across the condenser occurs.

The frequency of the oscillator depends both upon the resistance and the capacitance for any single voltage applied. The larger the resistance, the smaller the current that will pass through it, and so naturally the longer it will take for any amount of electricity to have passed through it. Also, the greater the capacity of the condenser the greater the charge that will be required to raise its potential to the striking value of the gas. Thus, the frequency of the circuit depends upon what is known as its time constant. The time constant is that time in which the condenser will charge to 63 percent of the potential applied to it, and it is equal to the resistance in ohms multiplied by the capacity in farads. The actual relationship showing the potential across the condenser at any time after the potential of the battery is applied is given by the following equation;

$$V = V_0 (1 - e^{\frac{t}{RC}}) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 1$$

where V is the voltage across the condenser, V_0 is the applied voltage, e is equal to 2.718 (the base of napeiran logarithms), t is the time, R is the resistance, and C is the capacity. The time is in seconds, the resistance, in ohms, and the capacity is in farads.

For example, if it is desired to find the potential across a one microfarad condenser after it has had a potential of 100 volts applied through a resistance of one megohm for 100th of a second, we substitute in the above equation:

$$V = 100 \left(1 - e^{\frac{.01}{10^6 \cdot 10^{-6}}}\right) \text{ or } V = 100 \left(1 - e^{-.01}\right)$$

we find that this value of the power of e is equal to .99 from the table, so that V = 1 volt. If we were to plot the values of the voltage across the condenser against the charging time on a suitable graph, we could obtain what is known as a logarithmic curve.

TABLE

Values of e^x and e^{-x}

x	e^x	e^{-x}	x	e^x	e^{-x}
0.00	1.0000	1.0000	0.25	1.2840	0.7788
0.01	1.0101	0.9900	0.30	1.3499	0.7408
0.02	1.0202	0.9802	0.35	1.4191	0.7047
0.03	1.0305	0.9704	0.40	1.4918	0.6703
0.04	1.0408	0.9608	0.45	1.5683	0.6376
0.05	1.0513	0.9512	0.50	1.6487	0.6065
0.06	1.0618	0.9418	0.55	1.7333	0.5770
0.07	1.0725	0.9324	0.60	1.8221	0.5488
0.08	1.0833	0.9231	0.65	1.9155	0.5220
0.09	1.0942	0.9139	0.70	2.0138	0.4966
0.10	1.1052	0.9048	0.75	2.1170	0.4724
0.11	1.1163	0.8958	0.80	2.2255	0.4493
0.12	1.1275	0.8869	0.85	2.3396	0.4274
0.13	1.1388	0.8781	0.90	2.4596	0.4066
0.14	1.1503	0.8694	0.95	2.5857	0.3867
0.15	1.1618	0.8607	1.00	2.7183	0.3679
0.16	1.1735	0.8521	1.25	3.4903	0.2870
0.17	1.1853	0.8437	1.30	3.6690	0.2730
0.18	1.1972	0.8353	1.35	3.8570	0.2590
0.19	1.2092	0.8270	1.40	4.0550	0.2470
0.20	1.2214	0.8187	1.45	4.2630	0.2350
0.21	1.2337	0.8106	1.50	4.4820	0.2230
0.22	1.2461	0.8025	2.00	7.3890	0.1350
0.23	1.2586	0.7945	2.50	12.1800	0.0821
0.24	1.2712	0.7866	3.00	20.0900	0.0498

Fundamentally, this is due to the fact that the current flowing through the resistor is proportional to the difference between the applied voltage and the voltage across the condenser at any time. This, of course, is just another way of saying that the current through the resistor obeys Ohm's law. Due to this fact, a lot of current flows at first when the voltage difference is great, and a smaller amount of current flows afterward until finally, when the potential across the condenser is equal to the voltage applied, then no current flows at all.

We can show that the current does actually vary in this manner by examining the relation between the current at any time and the other circuit constants. This relation is:

$$i = \frac{V_0}{E} e^{-\frac{t}{RC}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 2$$

where i is the charging current, V_0 is the applied potential, and R and the other letters have the same significance as in the previous formula. Also, we must remember that the voltage across the condenser is directly proportional to its charge and inversely proportional to its capacity, or:

$$V = \frac{Q}{C} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 3$$

where Q is the charge on the condenser, but Q equals the average current multiplied by the time. From these relationships, we find that the rate of change of voltage across the condenser with respect to time is equal to:

$$V = \frac{E}{RC} e^{-\frac{t}{RC}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 4$$

where V is the rate of change of voltage across the condenser with respect to time and the other letters have the same significance as in the previous formulae. Now if the sweep voltage is to be linear with respect to time, the rate of change of voltage V must be constant, or:

$$\frac{E}{RC} e^{-\frac{t}{RC}}$$

must be constant, and therefore, independent of the time t. This is obviously not the case, because t is included in the expression. Therefore, we can see both from this discussion and from the shape of the condenser charge curve that the voltage across the condenser does not vary linearly with the time. For this reason, the circuit is not suitable for television purposes, although if the striking potential of the tube is arranged so that only a small portion of the curve is used in conjunction with an amplifier, the output can be made sufficiently linear for commercial receivers.

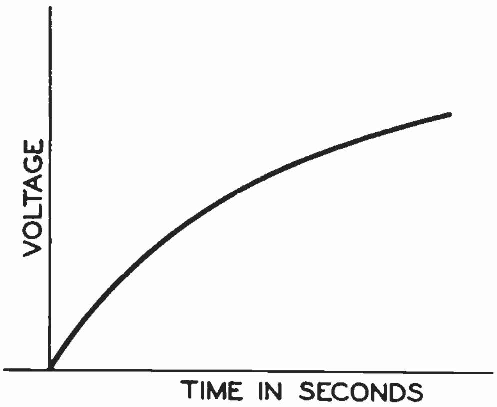
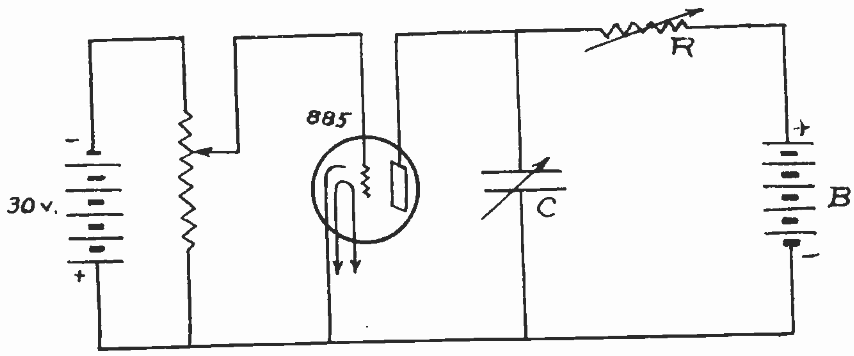


Fig. 4. A Condenser Charging Curve.

THE THYRATRON

The thyratron tube, or grid controlled rectifier is very similar to a normal three-element vacuum tube, except that it contains a gas at a comparatively low pressure. This gas is usually neon, argon, or mercury. The acthode is of the usual indirectly heated type, and the efficiency of some of these tubes may be as high as 95 percent or more. When a direct current (DC) potential is applied across the plate and cathode of the tube, and the grid is slowly changed from a highly negative bias to a more positive one, the current flow in the plate circuit is practically zero, and independent within limits, on the grid or plate potentials. At a certain point, depending upon the type of tube, the potentials applied and the grid bias, the gas suddenly ionizes, and the plate current rises to a value determined only by the external resistance in the plate circuit. That is, an arc discharge within the tube occurs. If the thyratron is substituted for the ordinary glow tube in the relaxation oscillator circuit, then the following action will take place. The potential across the condenser increases linearily with time due to the characteristics of the pentode tube. At a certain voltage value, determined by the bias on the thyratron, an arc will occur, and



THE THYRATRON OSCILLATOR

Fig. 5.

in almost negligible amount of time the voltage across the condenser drops to zero. In this circuit we theoretically have two independent controls, one determining the frequency (the grid of the pentode), and the other determining the amplitude (the grid of the thyratron). Actually, however, in most practical circuits, the one factor affects the other, so that after changing the frequency of a sweep circuit, it is usually necessary to readjust the amplitude control. Also the bias of the thyratron can only be varied within certain limits; obviously, if the bias is too little or too great, departure from linearity will occur. Notice that both the plate and grid circuits of the thyratron include resistance. Due to the negative resistance of the discharge occuring within the tube, resistors must be in these circuits to limit the currents to reasonable values. The 885 tube, which is very often used in sweep circuits, should, according to the manufacturer, have a thousand ohms of resistance for each volt in the grid circuit. The resistance included in the plate circuit is so small as compared to the plate resistance of the pentode that its effect upon the charging rate is usually quite negligible. Incidentally, we must caution against thinking that the full voltage of the DC source can be used, because even with the best pentode tube and other circuit conditions,the current change does fall off slightly toward the peak condenser voltage, and thus, if the amplitude is increased beyond a certain value, even the best sweep circuit will produce voltages which depart from linearity near their peak values.

The two sweep circuits used for the line and frame deflections of the cathode-ray tubes are similar except that their frequencies must be different and corresponding to the line and frame frequencies respectively. As the usual frame frequency is 30 cycles per second and assuming a raster of 441 lines, then the line frequency required will be 30 times 525 or 15,750 cycles per second. To obtain this difference in frequency, the capacity of the condenser used in the line sweep circuit is much less than that used in the frame sweep circuit. You will realize that if the capacity is small, then it will take only a small amount of current flowing for a certain length of time to a certain potential, whereas if the capacity is large, then much more current must flow for that same length of time to have the potential rise to the same value. However, the grid bias of the pentode tube is kept the same so that the current flow cannot change. Therefore, it will take a longer period of time for the same rate of current flow to charge up a large condenser than a small one.

If the sweep voltage from a thyratron circuit is applied directly to the deflection plate of a cathode-ray tube, it will only deflect the beam from the center to one side. This must occur because a DC and not an AC potential is applied to the plate, and the normal position of the spot is in the center of the screen. In most sweep circuit designs, the thyratron circuit is connected to the deflector plates by means of a small condenser. (See Fig. 6).

This condenser seves to allow deflection on either side of the center position due to the bound charge stored up when the sweep condenser charges, and the release when the discharge occurs.

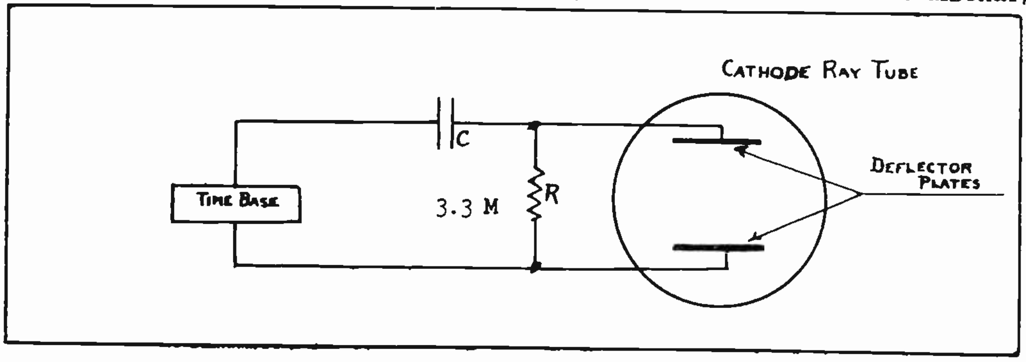


Fig. 6.

You will notice that the deflector plates are connected by a high resistance (several megohms.) Now when the charging condenser of the sweep circuit begins to acquire potential, a potential is also set up across the coupling condenser. This causes electrons to flow through the resistance connected across the deflector plates, and a corresponding difference of potential is applied to the plates and the beam is necessarily deflected. When the discharge occurs the direction of current flow through the resistor is reversed. Therefore, the potential across the resistor is reversed and the deflection of the beam is in the opposite direction. As the peak discharge potential is equal but opposite to the peak charge potential, the beam will be equally but oppositely deflected. Thus, with this arrangement, the deflection covers the tube face from one side of the screen to the other, and not just from center to one side. The main thing to observe in the design of such a circuit is that the time constant of the coupling condenser and the resistor across the deflector plates is greater than the flyback time. If this were not the case, then obviously the beam would be deflected across the screen, hover for a short time, come back to the center, stay there for a short time, and then repeat the trace. This is undesirable, so the capacity of the coupling condenser and the resistance across the deflector plates must be kept high especially in the case of the frame frequency. Incidentally, apart from deflection considerations, if the resistor were not connected across the deflector plates, the latter would acquire a charge from the electron beam which wlll cause various effects under different conditions including defocusing and even deflection of the beam right off the screen.

As we mentioned previously, the thyratron possesses several disadvantages. One of the most important we have not discussed. This difficulty is due to the fact that slight variations in the potential necessary to cause a thyratron to fire varies over periods of time. For synchronizing purposes this potential should be extremely constant as will be seen in the following paragraphs. This and the other disadvantages of the tube have led to the design of more reliable trigger devices. One of these is popularly known as the blocking oscillator.

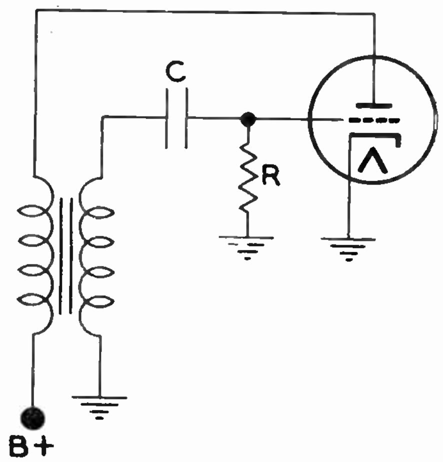


Fig. 7.
The basic blocking oscillator.

The blocking oscillator is shown in Fig. 7. To understand operation of this circuit, consider what occurs when there is a slight disturbance in the circuit such as would arise when the power was switched on. If the grid is driven positive, the flow of electrons to the plate is increased. Further, if the transformer windings are properly oriented, the voltage transferred back to the grid will act to further aid the positive voltage rise at the grid. This, in turn, will increase the plate current still more -- and the cumulative action of the continuing voltage increase will soon result in a flow of grid current, charging condenser C. If the grid resistor, R, is sufficiently high, the electrons stored in C will be unable to return immediately to the cathode and the grid will attain a sufficiently high negative voltage to cut off the tube. How long the tube remains in this condition is a direct function of the time constant (R x C) of the grid resistor and condenser. The charge on the condenser will leak off gradually through R. When the charge has diminished sufficiently so that the bias is no longer exceeded, the current within the tube will commenct to flow again. Each cycle, then, consists of a short flow of plate current, the tube becoming "blocked" or cut-off until the start of the next cycle. The plate and grid waveforms in Fig. 8 illustrate the circuit conditions more fully.

Since the frequency of the oscillator is directly controlled by the constants of R and C, making either one adjustable will permit altering the oscillator frequency. For convenience, the resistor is devided into two units and one is made variable.

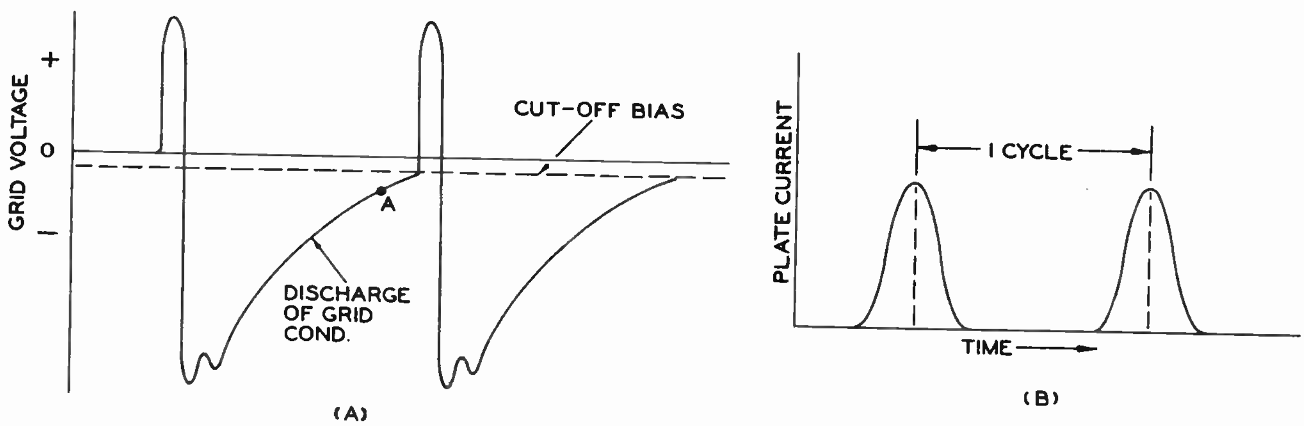


Fig. 8. (A) The grid, and (B) the plate waveforms of a blocking oscillator.

To adapt the oscillator for television use, modification in two respects is required. First, the oscillator must be capable of generating a saw-tooth wave; second, provision must be made to enable control of the oscillator frequency by the incoming synchronizing pulses of the television signal. The circuit shown in Fig. 9 incorporates these modifications

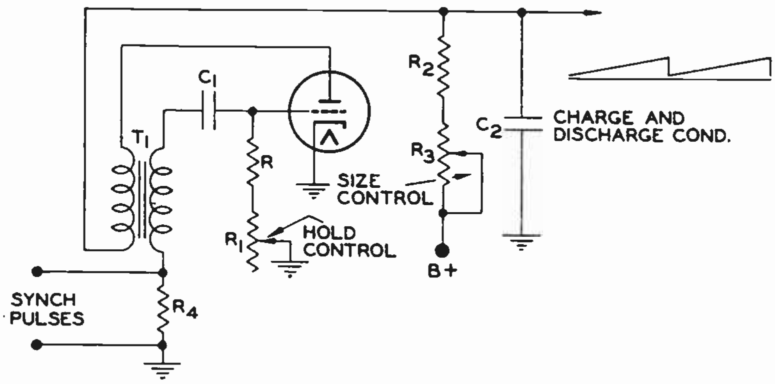


Fig. 9. The blocking oscillator designed to generate saw-tooth waves.

For the generation of saw-tooth waves, condenser C_2 is used. During the interval when the tube is non-conducting, C_2 is slowly charging through R_2 and R_3. From Fig. 4 the condenser charging curve, we note that if we utilize only only the beginning portion of the curve, that essentially a linear rise in voltage will be obtained. At the end of the rise, the condenser is discharged (during the short interval the tube is conducting). When the tube reverts to its non-conducting state, we have the start of the second saw-tooth wave or cycle.

The rate at which C_2 charges is controllable by R_3. If the full value of R_3 is placed in the circuit C_2 will charge at a slower rate, with the result that a smaller voltage will appear across C_2 at the time the tube becomes conducting. On the other hand, shorting out part or all of R_3 will increase the rate of charge of C_2 proportionately. Consequently, within any given time interval, the swing or amplitude of the saw-tooth wave generated will be directly dependent upon the setting of R_3. At the cathode-ray tube, the area covered by the electron beam is governed by the amplitude of the saw-tooth deflection wave. Consequently, R_3 will control the size of the image on the screen. This accounts for the name of "size" control. The discharge of C_2 occurs when the tube conducts heavily, since at this moment C_2 is offered a low-resistance discharge path through the tube. The greater the decrease in the tube's resistance, the more rapid the condenser discharge and the faster the retrace of the electron beam. In practice, the horizontal retrace speed is ten times faster than the forward speed; in the vertical system, the retrace is approximately 15 times faster than the downward travel.

To obtain the same image on the screen as is televised in the studio, close synchronization must be maintained. For this purpose, horizontal and vertical synchronizing pulese are inserted into the video signal. After the signal has been demodulated in the receiver, the pulses are separated or clipped from the camera portion of the signal and applied to the proper sweep oscillators for control.

The point of application of a synchronizing pulse to the blocking oscillator is shown in Fig. 9. The pulse appears across R_4 and acts directly on the grid of the tube. The most effective point of oscillator control is obtained if the pulse is applied just slightly before the oscillator comes out of cutoff, such as point A in Fig. 8. A positive pulse at this instant would pre-maturely trigger the oscillator, forcing it out of cut-off and initiating the start of a new cycle. If a pulse is applied at this same moment in each cycle, it will lock the oscillator in step with its own frequency and the two will be in synchronism. Note that upon the application of each synchronizing pulse, the tube conducts heavily. C_2 discharges and the electron beam retraces. At the end of the cycle the application of the next pulse finds the beam again at the extreme right-hand side of the screen, ready for a retrace.

The oscillator will remain locked-in so long as the synchronizing pulses and the oscillator frequency are sufficiently close to each other. However, if the oscillator slips out of control, then a series of over-lapping images will be obtained on the screen, completely destroying the enjoyment of the broadcast. Under these circumstances, adjustment of the hold control is required in order to bring the oscillator back into the locked-in condition.

THE MULTIVIBRATOR

A second type of sweep oscillator which has been widely used is the multivibrator circuit shown in Fig. 10. Essentially the multivibrator is a two-stage amplifier, with the output voltage of the second tube fed back to the grid of the first tube. The plate voltage variations of each tube are 180° out-of-phase with the grid voltage of the same tube. Hence, with a two-stage amplifier the phase difference between the grid voltage of the first tube and the plate voltage of the last tube is 360° out of phase. Due to this, the feedback will sustain oscillations.

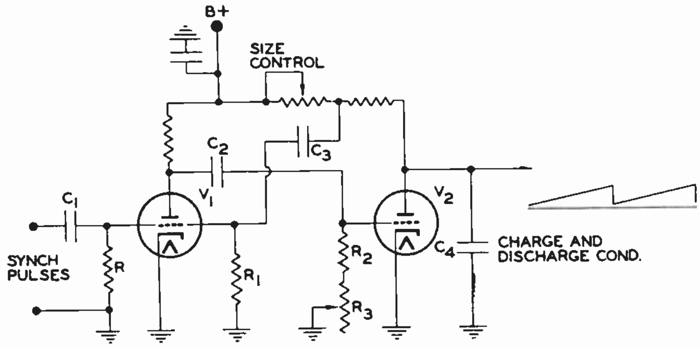


Fig. 10. A multivibrator oscillator.

Analysis of the circuit operation indicates that only one tube in the circuit is functioning at any one time. Thus, let us suppose that a disturbance in the circuit acts in such a manner as to increase the current through V_1. The increased current will decrease the plate voltage of V_1 and the decrease will appear at the grid of V_2 as a negative voltage by virtue of the coupling condenser, C2. The negative voltage at V_2 will reduce its plate current, thereby raising the plate voltage. Due to the connecting condenser, C_3 a positive voltage will appear across R_1, further aiding the initial rise of grid voltage at this tube. The increased plate current of V_1, as a result of the additional positive grid voltage, will again lower the plate voltage at this tube. The grid of V_2 will go more negative, until, when the cumulative effects are sufficiently large, V_2 is driven into cut-off. At this moment, only V_1 is passing current. The length of time that V_2 is kept in the non-conductive state will depend upon the time constant of the grid network of V_2; namely , C_2, and $R_2 + R_3$. The lowering of the voltage at the plate of V_1 has produced a negative charge (with respect to ground for V_2) across C_2. It is this negative charge which keeps V_2 cut-off. Until this charge has been able to leak off through R_2 R_3 and V_1, no conduction through V_2 can occur. Adjustment of R_3 will permit variation in length of time it takes C_2 to discharge which will, in turn, be one determining factor in the frequency of the oscillator.

When the grid voltage of V_2 has decreased sufficiently to permit current flow, the reverse of the conditions described above will take place, cumulating in the cut-off of V_1. The flow of current through V_2 will lower its plate voltage and this decrease will be transmitted to the grid of V_1 via C_3. The plate current of V_1 will decrease in proportion, increasing the plate voltage of V_1. The positive voltage reflected back to V_2 will further increase its current and decrease V_2's plate voltage. While this sequence of events is described rather slowly, the cumulative rise of current in one tube and its decrease in the other occur very rapidly. The end result is a high current flowing in one tube, while the transmitted negative charge brings the other tube to cut-off. The length of time that V_1 is kept non-conducting will depend upon the length of time required by C_3 to discharge its excess electrons through R_1 and V_2. When V_1 is able to conduct, the quick switch over is made again. This cycle of events continues for as long as the circuit is in operation.

To utilize the multivibrator in a television receiver, provision is made to receive the proper synchronizing pulses and to generate saw-tooth voltages. This is shown in Fig. 10. When V_2 is non-conducting, C_4 is slowly charging through R_5 and R_6. The synchronizing pulse is applied to V_1 and is negative so as to drive V_1 to cut-off. This immediately brings V_2 into conduction, discharging C_4. The multivibrator is so designed that V_2 conducts only long enough to discharge C_4, whereupon V_2 is cut off and C_4 starts another saw-tooth cycle.

CATHODE-COUPLED MULTIVIBRATOR

A modified version of the multivobrator, shown in Fig. 11, has been widely employed. In this unit, feedback is accomplished in two ways: through the coupling condesner, C_2, and the common un-bypassed cathode resistor, R_k.

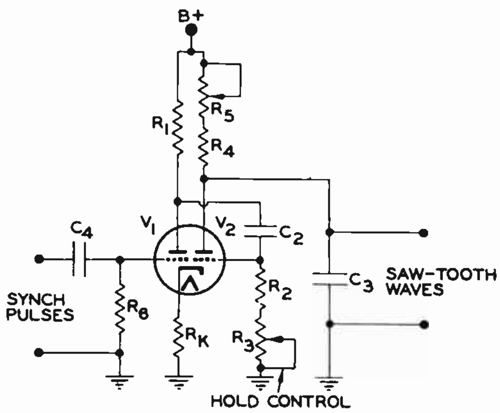


Fig. 11.
The cathode-coupled multivibrator.

Any change which occurs in the plate circuit of V_1 is applied to the grid circuit of V_2. All changes in V_2 are refledted across R_k and this, in turn, affects V_1. If a disturbance in the circuit should cause the plate current of V_1 to increase, the plate potential of this tube will decrease. This decrease will reflect back to V_2 via C_2 and swiftly drive V_2 to cut-off in a manner similar to that described above for the multivibrator. The length of time V_2 remains inactive depends upon the time constant of C_2 and R_2 plus R_3. When V_2 is again in operating condition, current rapidly increases, developing a sufficiently large negative voltage across R_k to bias V_1 to cut-off. V_2 continues to conduct because when V_1 is brought to current cut-off, the positive increase in plate voltage (of V_1) couples a positive charge into the grid circuit of V_2. This positive grid voltage overcomes, to a large extent, the negative bias across R_k and permits V_2 to conduct. While V_2 is conducting, C_3 is discharging through the tube and causing the beam to retrace across the screen. When the grid of V_2 draws enough electrons (due to its positive charge) to become blocked, the negative bias across R_k decreases and V_1 starts to conduct again. C_3 is now charging slowly, developing the saw-tooth wave. R_3 is the controlling factor over the frequency of the unit and hence it would be labeled "hold" control. R_5 governs the rate of charge of C_3 and is the "size" control.

DEFLECTION COILS

The saw-tooth voltage waves, when applied to a set of deflection plates, will produce the proper deflection of the electrom beam. On the other hand, applying the same voltage to a set of deflection coils will not result in a linear deflection of the beam across the screen. The reason is due to the fact that a saw-tooth applied across an inductance does not produce a saw-tooth current and in electromagnetic deflection, the coil, the magnetic flux and the beam deflection are all directly related. By modifying the form of the voltage applied to the deflection coils, the proper beam deflection can be obtained. The modification is readily achieved and is discussed in the lessons covering receiver design and operation.

SYNCHRONIZING

The sweep circuits at the transmitter and receiver must be synchronous and in order to maintain this arrangement, special signals must be transmitted from the scanner at the originating end to the scanner at the reproducing end. Two signals are usually used, one after each line and one after each frame of the picture. These signals are generated by simple vacuum tube circuits fed from the proper sweep circuit. One is usually of a greater magnitude than the other or has a different waveform so that they can be distinguished at the receiver when applied to the proper sweep circuit. If amplitude selection is used, the frame signal is of a greater magnitude and a resistance network is used in series with the input of the frame sweep circuit so that only a large signal will influence it. As the frame change only occurs after the last line, the introduction of the frame synchronizing signal to the line sweep circuit does not cause any trouble. When differently shaped waves are used for the vertical and horizontal sweep circuits, wave front selectors are used to separate the horizontal and vertical synchronizing impulses. Simple arrangements of condensers and resistors can be made to correspond only to steeply fronted waves.

Many television systems use a simple frequency filter to separate the two synchronizing signals. As the line synchronizing signal occurs several hundred times as often and, if of shorter duration than the frame synchronizing signal, then its frequency must be much higher. Obviously then, they can be easily separated by means of simple frequency filters composed of a condenser and resistor network.

DEFLECTOR COILS

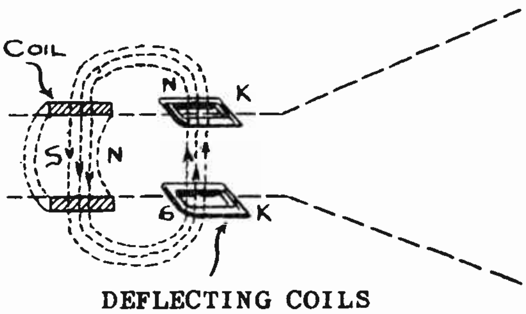
If electromagnetic scanning is used, various types of coils may be used to provide the scanning fields. The design of the coil is dependent upon many factors including the preservation of the saw-tooth waveform of the current passing through them, the frequency of the sweep circuit for which the coils are to be used, etc. Iron core coils are used for scanning. The inductance of the coils must obviously be kept low, otherwise the attenuation at the higher frequencies would become extremely serious and distortion of the saw-tooth waveform would result. Various means are resorted to to maintain this condition. Very often additional amplifier tubes are used in conjunction with the sweep circuits so that large output sweep currents are available and so only coils having a reasonable number of turns need be employed to produce the necessary magnetic flux. Sometimes the neck of the cathode ray tube is constricted between the electron gun and the screen so that the coils can be placed closer to the beam and smaller magnetic fields can therefore be used. The main feature of the iron core coil is its economy with regard to the scanning currents required because of the influence of the iron on the field distribution. The lines of force travel through the iron rather than through the air so that the magnetic field of the coils is confined to the location where it is of actual value. Usually a complete return iron yoke is used so that the stray fields will be reduced to a minimum. One serious disadvantage of iron core coils is the prolongation of the fly-back time. This may seriously interfere with the picture raster, and some of the workers in the field use a small air gap between the two coil units. By adjusting the length of the gap, the reluctance of the magnetic circuit can be varied and the fly-back time can be kept within reasonable limits.

When both magnetic focusing and deflection is employed, the line coils are usually placed inside the magnetic focusing coil and thus minimum interference occurs. This might sound strange unless one remembers that inside the magnetic focusing coil the magnetic field of the coil and the magnetic scanning field will be exactly at tight angles to one another and therefore, not interfere, whereas if they are separated by a small distance the lines of force from the focusing coil will have a sizable component in the same direction as the scanning field. Of course, iron core coils are more suitable for the frame scan than the line scan because of the former's lower frequency.

Extreme care must be taken in the placing of the coils and also in their design to prevent one set of coils interfering wtth the other. Very serious distortions of the pictureraster will occur if the interlinkage occurs. When magnetic focusing is usedas well as magnetic scanning, considerable difficulty is often encountered to prevent the various magnetic fields from interfering with one another. Magnetic shields must be used, and the various wires must be kept well apart. So serious are the difficulties that are sometimes encountered that some manufacturers of television receivers have abandoned the use of both magnetic focusing and magnetic deflection, and are using electrostatic focusing and magnetic deflection. If the latter is not adopted, variation in the vocus of the spot, distortion of the raster, and deflection of the raster as a whole may result. When electrostatic focusing and magnetic deflection is used, however, the focus of the spot is not destroyed under any conditions although a certain amount of astigmatism may occur due to a non-uniform field between the deflector coils. This can be overcome by shaping the coils if they are air core, or shaping the iron core if of that design. In either case a uniform magnetic field may be produced and consequently distortion of the spot may be eliminated.

INTERLACED SCANNING

If two frequencies are used in the manner described above, lines across the raster will be formed successively. This is called sequential scanning and is the simplest type used. It has been found that if the raster is scanned in a different manner, not successively, then the flicker of the picture is reduced and the apparent definition is improved. This process is called interlaced scanning. The simplest form of this scanning is interlacing of two fields. To accomplish this, every other line is scanned first down the whole depth of the frame. Then the odd lines are scanned to complete the scanning of the raster. Most cathode-ray systems use a two field interlacing arrangement, but in many mechanical systems, three fields or even more may be used.



DEFLECTING COILS
Fig. 12.

If a raster of 525 lines is used, and a frame frequency of 30 per second, then the horizontal or line scan must have a frequency of 30 x 525 or 15,750 cycles per second. If an interlacing arrangement is used wherein the total number of lines per frame is 525 and two interlacing fields are used, then there will be 262 1/2 lines per field, but the line frequency will be the same as before. The frequency of the vertical scann must be twice as great, however. That is, must have a frequency of 60 cycles rather than 30 cycles per second.

You will realize that the scanning lines are not exactly horizontal but slanted. This, of course, does not have any deleterious effect as far as the picture is concerned, but it makes possible a very simple arrangement ot accomplish the two field interlacing in which we are interested. The frequencies of the line and frame scans are so arranged so that each field will end one-half line short. That is, the last line of the raster will be cut in half by the vertwill end one-half line short. That is, the last line of the raster will be cut in half by the vertical scan. The next field, therefore, begins with half a line, proceeds in the normal manner to the bottom of the raster where this time the frame fly-back and the line fly-back synchronize so that the next field begins with a full line. Thus, the total frame will consist of an odd number of lines. For instance, in the two interlaced foeld systems now being widely used, each field consists of 262 1/2 lines and therefore uses a frame of 525 lines. The placement of the odd lines between the even lines is due simply to this half line cut-off arrangement. This will be made clearer by the diagram in Figs. 13 and 14. Even line interlacing has been used by Farnsworth, but it has assumed no commercial importance to date. Also triple and even quadruple interlacings have been used, in fact some television machines manufactured by A. T. I. use a triple interlaced field but these methods have not as yet been widely used in cathode-ray tube practice.

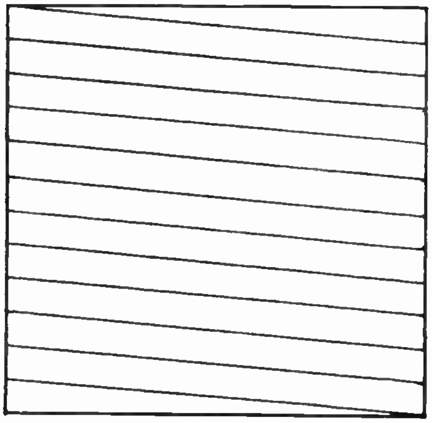


Fig. 13.
Sequential Scanning.

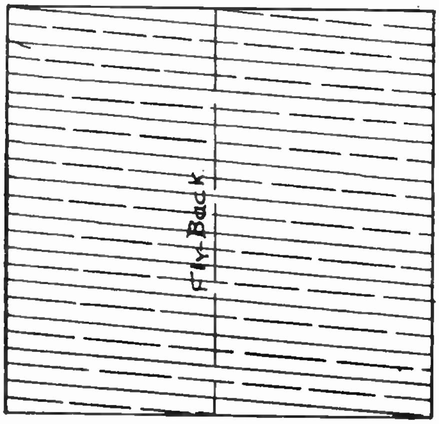


Fig. 14. Double interlaced scanning.

CHAPTER VIII
SPECIAL CIRCUITS

LIMITERS

Limiters, in one form or another, find application in many A.M., F.M., and television circuits. Their purpose, as their name implies is to limit or restrict the amplitude of the incoming signal. In A.M. receivers, the limiter is useful in reducing the effects of loud bursts of interference at the speaker. In F.M. receivers, the limiter removes any amplitude modulation existing in the received signal, thus presenting a purely F.M. signal to the discriminator. In television circuits, the limiter is employed in the clipper stages and in the F.M. audio system. Limiter circuits include diodes, triodes, and pentodes. A few of the more common applications will be discussed in the following sections.

DIODE LIMITERS

Series - Diode Limiters. -- It is well known, by this time, that a diode will conduct only when its plate is positive with respect to its cathode. If we keep the cathode at ground or zero potential, then the diode will start conducting as soon as its plate becomes one-half volt or more positive. As the plate becomes increasingly positive, the tube current will increase. The current will depend upon the amount of voltage which is applied to the tube. When the voltage is low, then the current will not increase as fast as the voltage. In the characteristic curve of a diode, Fig. 1, section AB would correspond to the low-voltage instance just cited. Note the gradual rise from A to B, indicating electrically that the opposition of the tube is such as to require a relatively large change in voltage for a small change in current.

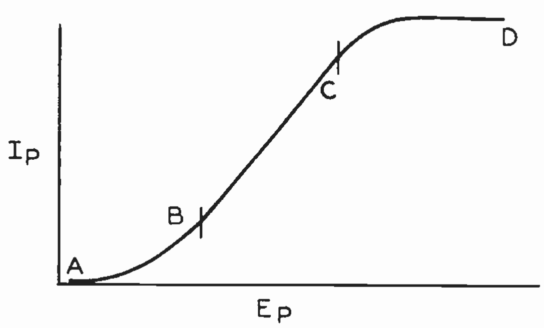


Fig. 1.

From B to C, Fig. 1, the curve becomes linear and the voltage and current rise in step with eachother. The slope of the curve will govern the resistance of the tube. If the slope is gradual, (the segment BC makes a small angle with the E_p axis), then the resistance offered by the tube is high. As the slope becomes steeper, the plate resistance of the tube decreases.

Beyond point C, the plate current is close to saturation and a further increase in plate voltage has very little effect on the plate current. The tube resistance now is very low.

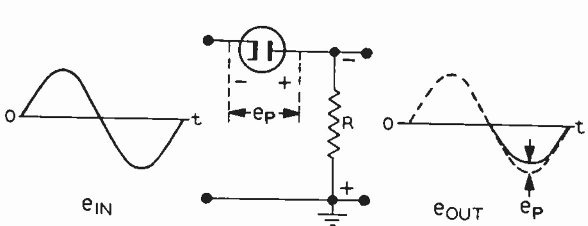


Fig. 2.

To limit the extent of positive signals, the diode can be connected as shown in Fig. 2. Upon the application of a signal voltage, e_{in}, the output voltage remains at zero throughout the positive half-cycle since the cathode is then more positive than its plate. During the negative half-cycle, the reverse situation is true and the tube conducts. Note that the negative half cycle voltage, which appears across R, is less than the negative half cycle of the input wave by the amount equal to the voltage lost across the tube.

In a similar manner, if we reverse the diode

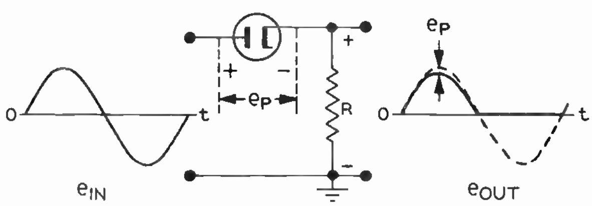


Fig. 3.

connections, we can limit the positive swing of the input voltage. This is shown in Fig. 3.

Parallel - Diode Limiters. -- Instead of connecting the diode tubes in series with the circuit, it is possible to connect them in parallel.

In Fig. 4A, the diode is connected so as to limit the positive portions of the incoming signals. The cathode is held at ground potential and the tube conducts throughout the entire positive half-cycle. Current flows through the tube and through the series resistor R. As R is large compared to the plate-to-cathode resistance of the diode, essentially the entire input voltage is developed across R and very little appears across the output terminals, C, D. What output voltage is obtained is actually the voltage appearing across the tube, e_p. On the negative half-cycle of the input wave, the diode is non-conductive, presenting an extremely high impedance across the circuit. The wave appearing across the input terminals AB is transferred with very little loss (in series resistor R) to the output terminals CD. It must be remembered, however, that this condition only holds when the tube is not conducting.

The circuit in Fig. 4A clips off the positive portion of any incoming signal. By reversing the tube connections across the circuit, we permit the positive half-cycles to pass, eliminating only the negative portion of the signal. The circuit is illustrated in Fig. 4B. No matter which way the diode is connected, its operation remains the same. It conducts only when its plate potential becomes positive with respect to the cathode.

The foregoing limiters clipped off one entire half section of a wave. An input voltage can be limited to any desirable positive or negative value by holding the proper diode electrode (cathode or plate) at the voltage by means of a battery or a biasing resistor. In Fig. 5., two such circuits are shown. The cathode of the diode in Fig. 5A is more positive than the plate by the value of E when no signal is applied at the input. As long as the input voltage remains less positive than the battery voltage, E, the diode functions as an open circuit and the output voltage equals the input voltage. If the input increases to a value greater than E the tube conducts. During this period of conduction, the output voltage will remain fixed at the battery voltage E. When the tube conducts, it can be considered as a short circuit, effectively placing the battery, E, across the output terminals. When the input voltage drops below a value E, the tube becomes non-conducting again. In this condition it acts as an open circuit across the line, permitting the signal to pass undiminished.

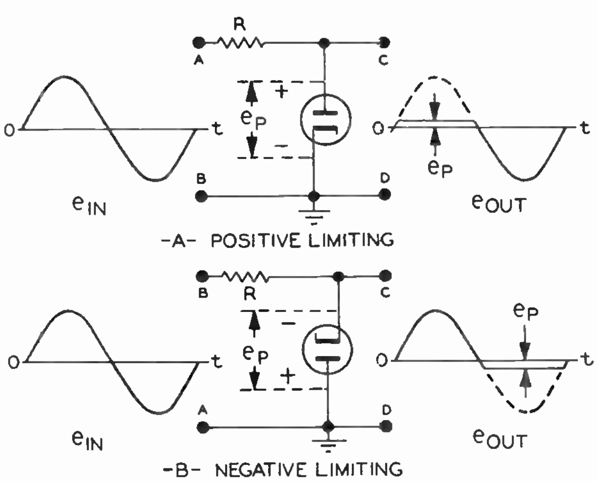


Fig. 4.

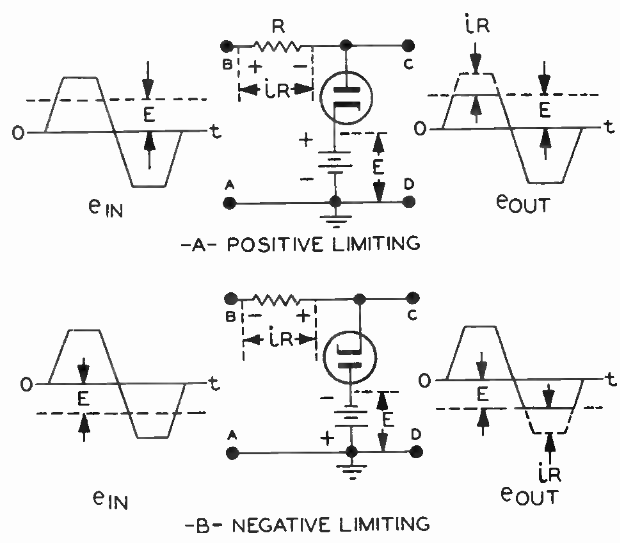


Fig. 5.

In the second circuit, Fig 5B, only the negative portion of an incoming signal is subjected to the limiting action. The plate of the reversed diode is negative by the value of battery voltage E. Thus, as long as the input voltage is positive or is less negative than E, the diode forms an open circuit and the output voltage is equal to the input voltage. When the input becomes more negative than E, the diode conducts and effectively connects the upper output terminal to the negative terminal of the battery. During this portion of the input cycle, the output voltage equals E and the difference between e_{in} and E appears as an IR drop across R.

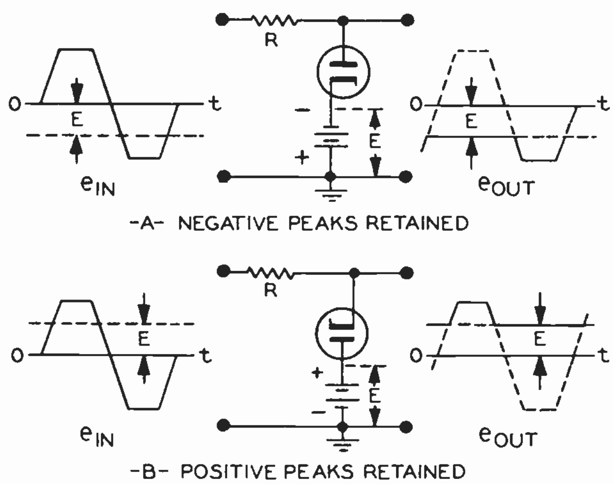


Fig. 6.

It is sometimes desirable to pass only the positive or negative extremity of a signal to a succeeding stage. To accomplish this, the two limiter circuits in Fig. 6 may be employed. In the first illustration, Fig. 6A, the entire portion of the input waveform above the negative potential E causes the diode to conduct, thus producing an output voltage which varies between the negative level of E and the negative extremity of E. In Fig. 6B, the diode conducts during the entire portion of the input signal which is less than the positive potential E. The output voltage then varies between the positive level of E and the positive extremity of the input waveform. In either case the difference between the value of E and e_{in}, during the time the diode conducts, is represented by the voltage drop across the series resistor R.

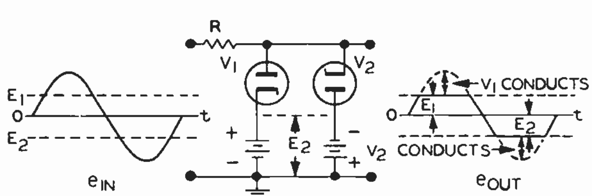


Fig. 7.

Double - Diode Limiting. -- It is further possible to limit both amplitude extremities of an input waveform at any desirable levels by placing two diodes in parallel in the limiter circuit. In Fig. 7, the diode V_1 is made to conduct whenever the input voltage e_{in} reaches a higher positive value than E_1, thus limiting the positive half cycle to the value of E_1. The diode V_2 is made to conduct whenever the input reaches a higher negative value than E_2, thus limiting the negative half-cycle to the value of E_2. The circuit represents a simple method of producing a satisfactory square-wave output with a sine-wave input voltage.

PRACTICAL APPLICATIONS

A simple limiter to prevent sharp bursts of static and other noise interference from reaching the speaker is shown in Fig. 8. The limiter is connected in series with the detected audio signal from the second detector load resistor R_1. Hence, it is a series diode limiter.

The operation of the limiter circuit is as follows: A constant signal carrier will develop a constant d.c. voltage across R_1 and R_2. The flow of current from the detector diode is such (plate to cathode) that point A is negative with respect to point B. Let us assume that 6 volts are developed between these two points due to the incoming carrier. The plate of V_2, the limiter diode is connected to point C. At this point the d.c. potential is half that of point A because R_1 and R_2 (in this particular instance) are equal. The plate of V_2, then, is 3 volts negative with respect to ground. The cathode of V_2 connects to point A through R_3 and R_4. Its potential is therefore equal to -6 volts.

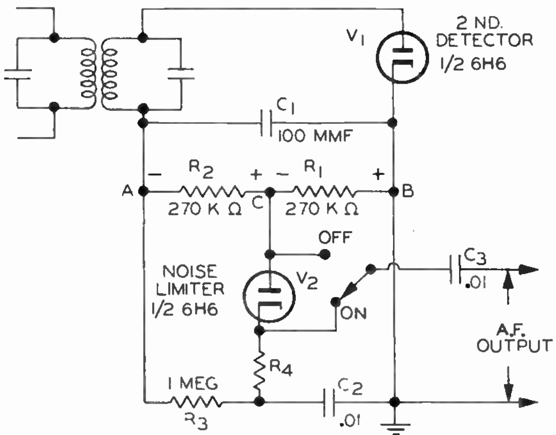


Fig. 8.

Under these conditions the plate of V_2 is 3 volts less negative (or more positive) than the cathode and the tube conducts. During conduction, the internal resistance of the diode falls to a fairly low value. This means, in Fig. 8, that the output condenser C_3, is connected through the diode to point C. The A.F. signal developed across R_1 is thus transferred to the output with only a slight loss due to the resistance of the intervening limiter diode. Aside from this loss in output signal, the noise limiter has very little effect on a normal signal.

In the above circuit, condenser C_2 is charged through the 1-megohm resistor to a value of -4.2 volts. Due to the values of R_3 and C_2, any appreciable change in this potential would require about .01 second. (The time constant of $R_1 + R_2$) C_1, however, is much less, being on the order of 50 microseconds. Consequently, if a sudden surge of interference reaches the detector, the plate of V_2 is driven highly negative while the cathode is unable to change its potential as rapidly due to the presence of C_2. As a result, V_2 stops conducting and C_3 is, in effect, disconnected from the second detector. There is no audio output. This condition will exist until the cathode reaches a more negative potential. By this time, the noise pulse has passed and the circuit is in a position to resume its normal operation.

The most important consideration in the design of this circuit is the choice of the values of C_2 and R_3. If their time constant is made too long, the set will be cut-off for noticeable periods of time. If it is made too short, the bursts of interference will, in some measure, reach the output and be heard. The time constant chosen, 0.01 second, is a compromise value.

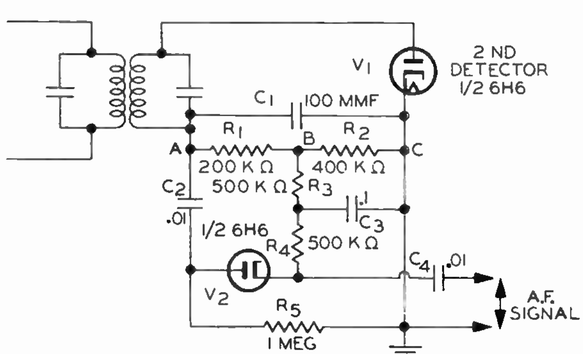


Fig. 9.

A variation of this circuit is the series limiter shown in Fig. 9. This circuit, while requiring several additional components, transfers more of the rectified A.F. signal to the audio amplifiers. Its operation follows closely that of Fig. 8. The cathode of the limiter diode, V2 is biased negatively relative to its plate by connection to the junction of detector load resistors R_1 and R_2 through resistors R_3 and R_4. The d.c. potential of the limiter plate is zero due to its connection through R_5 to ground. Thus V_2 is normally conducting and the A.F. signal developed across R_1 and R_2 is transferred to the A.F. amplifiers through C_2, the conducting diode (V_2) and C_4. Note that in this circuit, the full audio voltage is reaching the audio amplifiers, whereas previously only half the available signal was obtained.

The negative potential of the cathode of V_2 does not change readily because of the presence of R3 and C_3. The time constant of this filter is long and instantaneous changes in voltages are absorbed.

The foregoing represents the normal operation of the circuit, in the absence of any appreciable noise disturbances. When a noise impulse does arrive, the potential at point A is driven highly negative. This sharp increase is transferred via C_2 to R_5, making the plate end of this resistor negative with respect to ground. The cathode potential is unable to change rapidly due to R_3 and C_3 and therefore, for the moment, it retains its previous potential. As a result, V_2 is forced into non-conduction by its high negative plate potential and no A.F. signal reaches the audio amplifiers. By the time the cathode of V_2 does assume a more negative potential, the noise impulse has decayed.

Shunt Limiters. -- The simplest type of shunt diode noise limiter is shown in Fig. 10. The additional parts necessitated by this limiter are few, consisting only of a diode, a resistor, and a condenser. The second detector load circuit consists of C_1, R_1, and R_2. The time constant of this network is very low, 10 microseconds, permitting it to follow all voltage changes. The limiter tube plate circuit has a time constant of 1 second.

$$T = R_3 \times C_2 = 1 \text{ meg} \times 1 \text{ mfd} = 1 \text{ second.}$$

Consequently the plate voltage cannot change readily. Now let us see how this produces the desired limiting action.

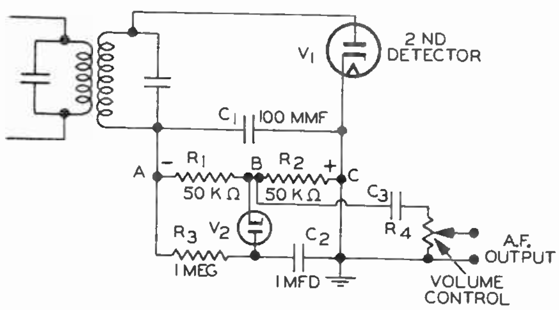


Fig. 10.

Assume that a constant carrier is making point A 10 volts negative with respect to point C. Point B is then 5 volts negative with respect to ground, and the cathode of V_2 is 5 volts positive with respect to its plate. The diode will therefore not conduct so long as this situation remains. The audio output is obtained from R_2, the amount of audio signal tapped off being controlled by the volume control, R_4. As long as V_2 is non-conductive, the circuit will function as a normal detector circuit.

At the application of a noise surge, point A will be driven considerably more negative than before. Point B will follow suit. The plate of V_2, however, will be unable to follow this sudden change of conditions because of the presence of R_3, C_2 and their long time constant. Therefore, the plate of V_2 will remain at -10 volts, while the cathode, connected to point B, will be considerably more negative because of the surge. Under these conditions, the tube will conduct, effectively shunting R_2 and decreasing the amount of audio signal reaching the volume control. Limiting action will cease when the voltage across C_2 changes to that of point A or the noise pulse disappears and point B returns to its previously low negative value. In either instance the diode, V_2, will cease to conduct, returning the circuit to its normal state.

A more efficient circuit is the one shown in Fig. 11. The basic second detector circuit is still V_1, C_1, R_1, and R_2. V_1 has been reversed, which means that the polarities across the detector load resistors are reversed. As in the previous shunt noise limiter, the cathode potential can change with the signal whereas the plate potential of V_2 lags, due to its relatively long time constant. The operation of this unit follows closely that of the previous limiter.

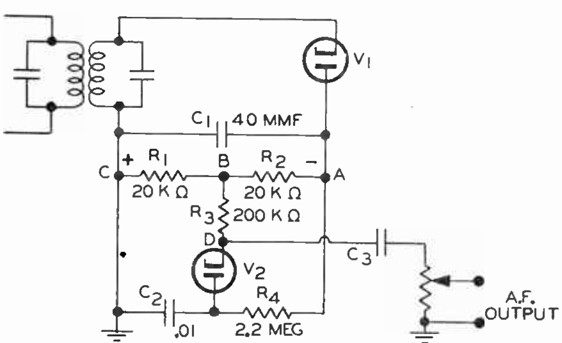


Fig. 11.

Assume a constant carrier produces a signal voltage of 10 volts between points A and C. The relative polarities of these points, with respect to ground are as shown in Fig. 11. Point B, being intermediate between A and C, would be -5 volts. V_2 plate is connected through R_4 to Point A and is therefore 10 volts negative. Since the plate of V_2 is more negative than its cathode, V_2 will not conduct normally. The audio output is taken from point B, through R_3 to the volume control. V_2 being non-conductive, does not affect the signal.

Suppose now that a sudden surge of noise voltage reaches the receiver. Point B (along with point A) will be driven highly negative. The plate of V_2, however, will temporarily remain at its previous value due to the long time constant of C_2 and R_4. Under these conditions, V_2 will conduct and only the audio signal voltage appearing across the relatively small resistance of V_2 will reach the volume control. When V_2 is conducting, it forms a voltage divider with R_3. However, since R_3 is considerably greater in value than V_2 (when it conducts), most of the voltage from point B will appear across R_3 and only a small portion of it across V_2. Note that when V_2 is non-conducting, all of the voltage across point B appears across V_2, and this is transferred to the volume control.

Limiting action ceases when the cathode of V_2 returns to a value less negative than the plate voltage.

TRIODE LIMITERS

Triode limiters are employed more extensively than diode limiters because, in most instances, sharper limiting action can be achieved. In addition, when the limiting action accurs in the plate circuit of a triode, we gain the benefit of the tube amplification. Triode limiting can be accomplished in the grid circuit, the plate circuit, or by the combined action of both circuits.

Grid Limiting. The grid-cathode circuit of a triode, tetrode, or pentode may be employed as a limiter circuit in exactly the same way as the plate-cathode circuit of the diode limiter illustrated in Figs. 4 and Fig. 5. By inserting a series grid resistor as shown in Fig. 12, which is very large compared to the grid-to-cathode resistance when grid current flows, essentially the entire positive half-cycle of the input voltage is limited to the voltage level of the cathode. For example, the grid-to-cathode resistance may drop from an infinite value, when the grid is negative with respect to the cathode, to a value on the order of 1,000 ohms, when the grid attempts to become positive with respect to the cathode. If a 1-megohm resistor is placed in series with the grid, the drop across the 1,000 ohm R_{gk} is negligible as compared to that which is developed across the 1-megohm resistor by the flow of grid current.

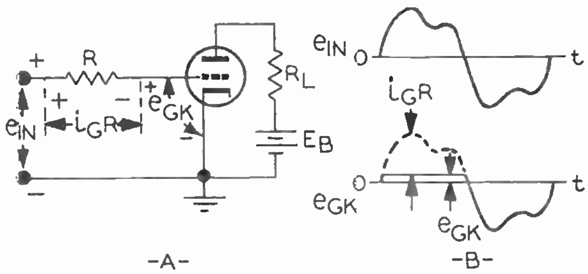


Fig. 12.

The grid limiter circuit shown in Fig. 12 is held normally at zero bias. During the positive portion of the input signal the grid attempts to swing positive. Grid current flows through the resistor R, developing an I_gR drop of such polarity as to oppose the positive input voltage. Since the full input voltage must appear as the sum of the drop across R and R_gk, the larger R is with respect to R_gk, the nearer the voltage on the grid is limited to that of the cathode. The I_gR drop may be considered as an automatic bias developed during the part of the input which causes grid current to flow.

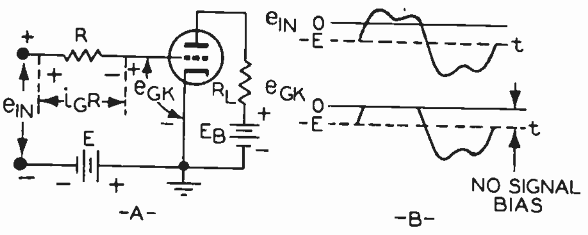


Fig. 13.

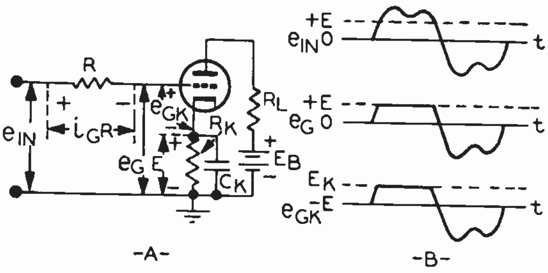


Fig. 14.

Alternate circuits for limiting the positive peaks of the input voltage are shown in Figs. 13 and 14. In Fig. 13, the tube is biased by the negative potential E supplied to the grid, with the cathode returned to ground. No grid current flows until the input signal e_{in} rises sufficiently to equal and effectively remove the biasing voltage E. Any further rise of e_{in} drives the grid positive with respect to the cathode, and grid current flow limits the signal on the grid by virtue of the I_gR drop across R.

In Fig. 14, Bias is developed between grid and cathode by the flow of plate current through the cathode resistance R_k which is by-passed by the large capacitor C_k. The grid is normally held at ground potential and thus is negative with respect to the cathode. Any positive signal E_{in} must drive the grid positive by an amount equal to the value of E before the biasing effect of R_k is removed. This is shown by the e_g waveform in Fig. 14 B. A further rise of the input voltage produces grid current which results in the limiting of the voltage at the grid. The grid-to-cathode voltage e_{gk} in Fig. 14 B illustrates the effect of R in preventing the grid from swinging appreciably above the cathode potential.

Saturation Limiting. Whenever a series-limiting resistor is used in the grid circuit, the grid cannot be driven to an appreciable positive voltage and, despite the positive amplitude of the input voltage, the maximum plate current which flows is that determined by the plate supply E_b and the resistance of the plate circuit at zero bias. Thus the minimum plate voltage is determined by the limiting action in the grid circuit. These plate current and plate voltage relationships are shown in Fig. 15.

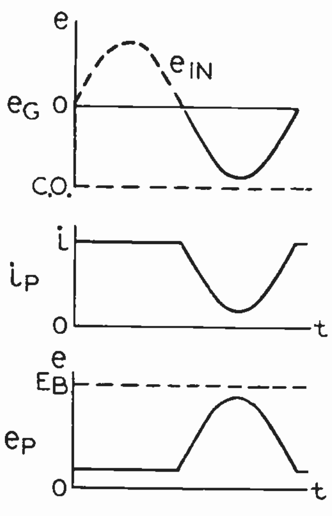


Fig. 15.

The grid-limiting resistor may be omitted, if the input signal comes from a low-impedance high-power source, and limiting in the plate circuit may still be realized. This is due to plate-circuit saturation and is usually referred to as saturation limiting. Plate-current saturation should not be confused with emission saturation since in tubes using oxidecoated cathodes there is no definite saturation value of emission current.

By using a large value of plate-load resistance R_L and a low plate-supply voltage E_b, saturation limiting may be produced by a relatively low amplitude of positive grid voltage. In any case, however, the plate current can never exceed the value E_b/R_L. In an actual circuit some small positive voltage must remain on this plate to attract electrons from the cathode, and the saturation plate current never quite equals E_b/R_L. In other words there remains across the tube a low voltage drop when the plate current is at saturation, since the plate-to-cathode resistance at saturation does not decrease to zero.

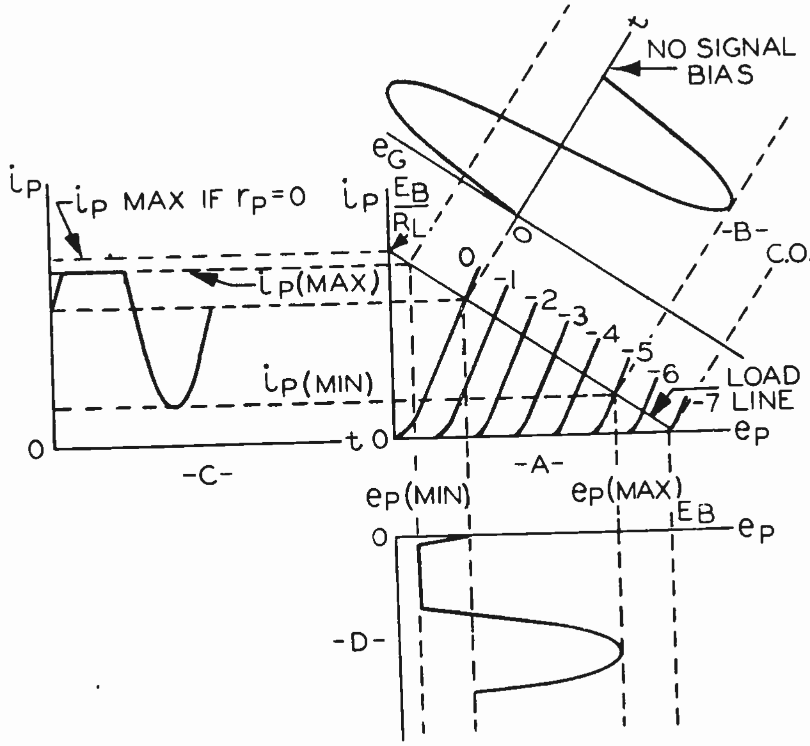


Fig. 16.

In Fig. 16, the I_p vs. E_p characteristic of a triode (A) is used to illustrate the effect of saturation limiting on the plate voltage. The input signal applied to the grid (B), which is normally at zero bias, is not of sufficient amplitude to drive the tube to cut-off on the negative swing but causes the plate current to saturate on the positive swing. The dotted extension of the load line describes the tube during the positive position of the input cycle. The maximum plate current (C) cannot exceed the value E_b/R_L no matter how high the amplitude of the positive grid signal, and is actually slightly less because of the low-saturation plate resistance which remains in the series with the load. The maximum plate current defines the lowest value to which the plate voltage can fall (D). During the remaining portion of the input cycle the grid controls the flow of plate current which in turn determines the shape of the plate-voltage waveform.

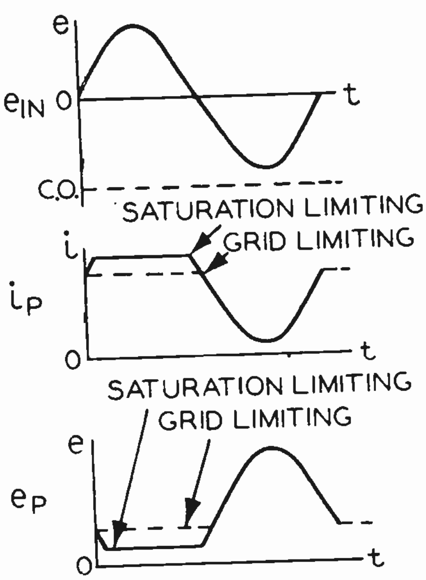


Fig. 17.

The results of saturation limiting are similar to those of grid limiting in that the negative-going portion of the plate voltage is affected. These are compared in Fig. 17. Saturation limiting has the advantage of producing an output wave of greater amplitude, but it has the disadvantage of requiring considerably more power to drive the grid.

Cut-off Limiting. Electron current through a vacuum tube can flow only from cathode to plate and from plate to cathode. Therefore, plate current cannot become a negative value. When the grid is driven to cut-off the plate current is decreased to zero and remains at zero during the time the grid is below cut-off. Since no current flows through the plate circuit when the tube is cut off there is no voltage developed across the load resistance and the plate is maintained at the full value of the plate-supply voltage. Thus a type of limiting is achieved in which the positive extreme of the plate waveform is flattened as a result of driving the grid beyond cut-off.

The cut-off voltage may be defined as the negative voltage, with respect to the cathode, to which the grid must be driven in order to prevent the flow of plate current. For any given type of tube this voltage level is a function of the plate-supply voltage and in the case of triodes may be approximated by the expression

$E_{co} = \frac{E_b}{u}$ where E is the plate supply voltage and u is the amplification factor of the tube. This relation is not valid in the cases of tetrodes and pentodes.

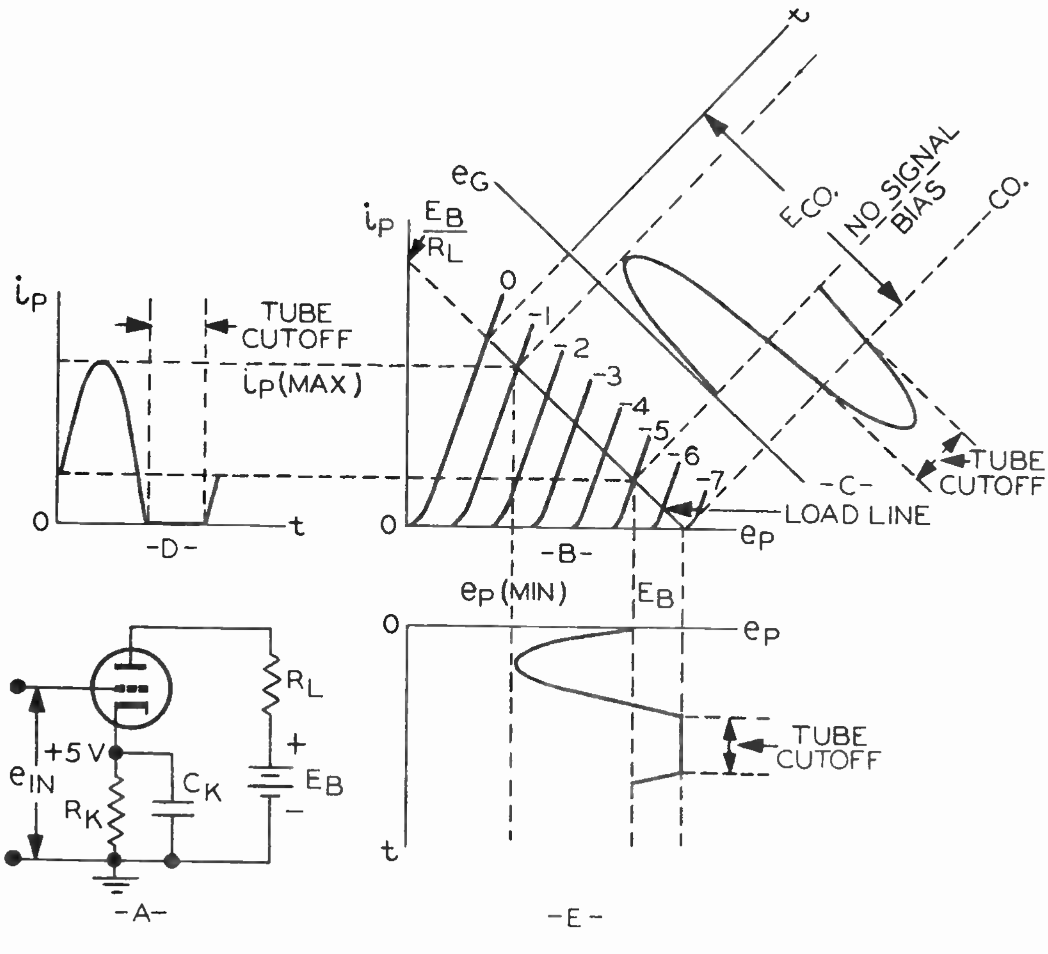


Fig. 18.

In Fig. 18 the I_p vs e_p characteristic of a triode is used to illustrate the limiting effect caused by driving the grid of an amplifier beyond cut-off. The grid normally is biased to -5 volts by the steady drop across R_k, (A). The value of E_b is such that the cutoff potential E_{co} is -7 volts. The maximum amplitude of the input voltage is 4 volts; thus the grid voltage (C) swings in a positive direction from -5 volts to -1 volt and in a negative direction from -5 volts to -9 volts. During the time that the grid voltage remains below cut-off the plate current remains at zero and the plate voltage is held at the level of E_b.

A combination of grid---- limiting and cut-off limiting may be employed in an amplifier circuit to produce a square wave from a sine wave. This is illustrated in Fig. 19. The amplitude of the input voltage is sufficiently high to hold the grid beyond cut-off for the greater part of the negative swing. The grid resistor R is on the order of 1-megohm and limits the grid voltage essentially to zero during the positive swing.

Square waves, which are used extensively in television transmitting and receiving equipment, can be produced by one of two methods, Either they can be formed directly, as in the multivibrator, or else they can be formed by limiters. In each of these methods, we take an input sine wave and by clipping the top of each half cycle, can produce a fairly well shaped square wave. It is not unusual to find three or four limiters or clippers and amplifiers, whose sole purpose is to amplify and clip the tops of the tops of the wave when perfect square waves are desired.

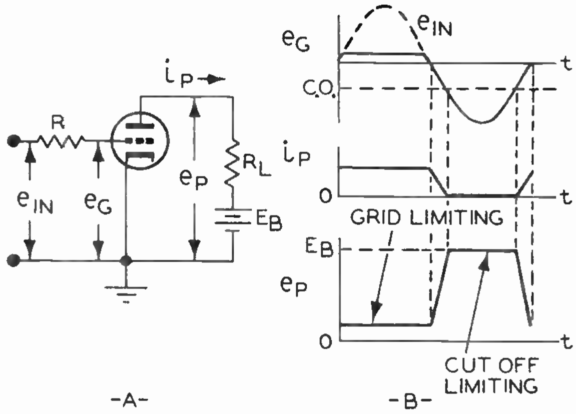


Fig. 19.

CLAMPING CIRCUITS

A circuit which holds either extreme of a waveform to a given reference level of potential is called a clamping circuit, a d-c restorer or a baseline stabilizer. In television, the term d.c. restorer is most frequently found. Such circuits are divided roughly into two classifications. The first, diode and grid clamping, clamps either amplitude extreme and allows the waveform to extend in only one direction from the reference potential. The second, synchronized clamping, maintains the output potential at a fixed level until a synchronizing pulse is applied, when the output potential is allowed to follow the input. At the end of the synchronizing pulse the output voltage is returned immediately to the reference level.

To demonstrate the utility of clamping circuits, a brief review of the action of coupling networks is useful. In coupling between stages in radio and television circuits a coupling capacitor almost always must be used to keep the high positive d.c. plate potential of the first tube isolated from the grid of the second tube. It is desirable that only the varying component of the plate potential be transmitted to the grid as a signal varying above and below some fixed reference level. If the lower end of the grid-leak resistor is grounded, the signal varies about ground. If a biasing potential is employed, the signal applied to the grid varies above and below this d.c. bias voltage.

In class A operation, the latter condition is desirable. The biasing potential is adjusted to the center of the Class A range and the varying potential is kept within the limits of this range. The center of the grid swing is fixed, and the amplitude variation of the grid voltage directly affects the amplitude of the plate-voltage swing. This is exactly the condition desired in Class A operation, Fig. 20 A.

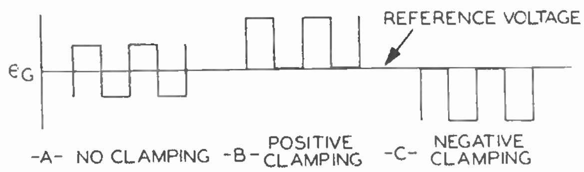


Fig. 20.

In other circuits, however, the waveform swing must be entirely above or entirely below the reference voltage, instead of alternating on both sides of it (Fig. 20B and 20C).

For these applications a clamping circuit is used to hold either the positive extreme or the negative extreme of the waveform to the desired level.

The output of an ordinary R-C coupling circuit is alternating in character about the average voltage level of the applied waveform. After the coupling capacitor charges to the average applied voltage, any decrease in applied voltage causes the output voltage of the R-C network to swing negative. Any increase above the average causes the output voltage to swing positive. Now, if the capacitor can be made to charge, say to the minimum applied voltage and no more, any swing has to be in the positive direction, and the output voltage varies between zero and some positive value, depending on the amplitude of the input signal. If, on the other hand, the capacitor can be made to charge to the maximum applied voltage and remain charged to that level, any swing necessarily is in the negative direction, and the output voltage varies between zero and some negative value, depending on the amplitude of the input signal. In the first case the bottom of the output waveform is clamped to zero (Fig. 20B), and in the second case the top of the output waveform is clamped to zero (Fig. 20C).

Diode Clamping. The simplest type of clamping circuit utilizes a diode in conjunction with the ordinary R-C coupling circuit. Consider the case in which the capacitor voltage is maintained at the minimum applied voltage (Fig. 21). In order to understand the action of this circuit, the following significant point should be kept in mind: If the cathode of a diode is made negative with respect to the plate, or the plate positive with respect to the cathode, electrons flow from cathode to plate and the tube constitutes a low resistance. On the other hand, if the cathode is made positive with respect to the plate or the plate negative with respect to the cathode, no current flows and the tube may be considered an open circuit.

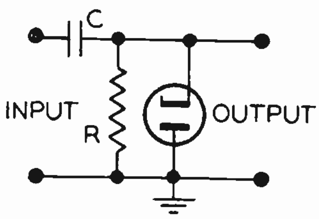


Fig. 21.

The plate-voltage variation of a circuit producing a square-wave output (Fig. 22) is typical of the input applied to the clamping circuit of Fig. 21. In this clamping circuit, capacitor C charges gradually through the high resistance R. After a period of time, depending on the R-C time constant, the charge on the capacitor reaches 50 volts, the base of the input waveform. The problem is to maintain the charge at this value in spite of the tendency of the capacitor to charge to a higher level when the applied voltage goes to +150 volts.

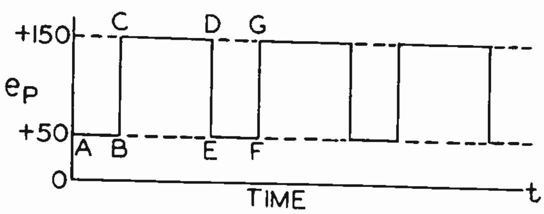


Fig. 22.

Assuming that a steady voltage equal in magnitude to that at point A in Fig. 22 has been applied for some time, the capacitor in Fig. 21 may be considered as being charged to 50 volts. During the time between A and B the charge on the capacitor is equal to the applied voltage and no current flows. Then at point B the applied potential suddenly increases to 150 volts. Since it is impossible for the charge on the capacitor to change instantaneously, the difference between the 150 volts applied and the 50 volts across the capacitor must appear across R. This difference of 100 volts becomes the output voltage.

The fact that a voltage appears across R (Fig. 21) indicates that a current is flowing through it. This current flow adds to the charge on C. Ordinarily the R-C time constant would be very long and the actual charge added to C would be extremely small. For simplicity, assume that the 150 volt potential is applied for a time equal to 1/10 R-C or from point C to point D. Since the cathode of the diode is positive with respect to the anode, the tube is in effect an open circuit and R is a high resistance. During a time equal to 1/10 R-C the charge on the capacitor increases exponentially by 10 percent of 100 volts, or 10 volts, making the total charge 60 volts. During the same time the drop across the resistance decreases exponentially by 10 volts to a value of 90 volts leaving the sum of e_R and e_C still equal to the applied potential of 150 volts.

Now at point D, the applied voltage suddenly drops back to 50 volts. But the capacitor is charged to 60 volts. This would leave an output voltage across R of 10 volts negative with respect to ground -- a condition it is hoped to avoid. In order for the output to return to zero very quickly the capacitor must discharge the extra 10 volts through a very short R-C path.

In Fig. 21 the cathode of the diode is connected to the high side of R and the plate is grounded. Any output voltage which is negative with respect to ground makes the cathode negative with respect to the plate. In this state the diode conducts and becomes, in effect a very low-resistance discharge path for the capacitor until the charge is again equal to the applied voltage and the output voltage returns to zero. These conditions are illustrated in Fig. 23.

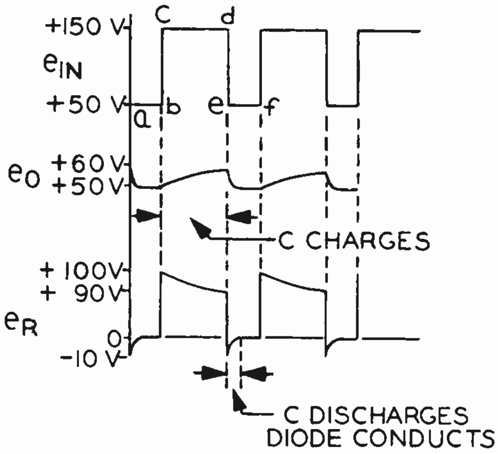


Fig. 23.

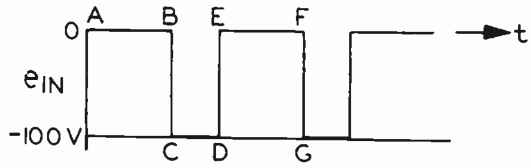


Fig. 24.

To illustrate the operation of the positive clamping circuit further, it is assumed that the waveform shown in Fig. 24 is applied to the clamping circuit of Fig. 21. Since at point A the input voltage is zero, the output voltage is zero and remains so until point B is reached. At this time the input voltage drops suddenly to -100 volts at point C. Since the capacitor cannot change its charge instantaneously, the output voltage across R also drops suddenly to -100 volts. Since the cathode of the diode is 100 volts negative with respect to the plate, the tube conducts heavily, charging the capacitor very rapidly through a short R-C until the capacitor voltage becomes equal to the applied voltage. At this time the output voltage has returned to zero and the diode becomes non- conducting. As long as the input remains at -100 volts, from points C and D, the output voltage remains at zero potential.

At point D, the input voltage changes back to zero, a rise of 100 volts in the positive direction (100 to 0). This rise produces a rise of 100 volts (0 to 100) across R, as the capacitor again cannot change its charge instantaneously. The capacitor must now discharge very slowly as the diode is nonconducting and the high-resistance path through R must be utilized.

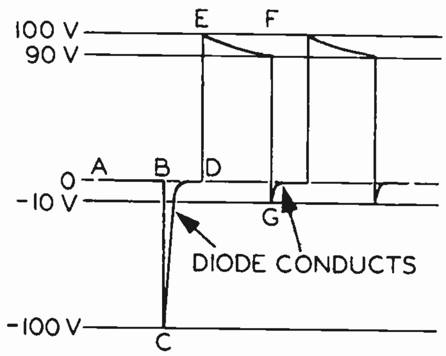


Fig. 25.

Assuming again a time for discharge from points E to F or one-tenth R-C, the voltage across the capacitor at F, and thus the output voltage, decreases to 90 volts, since the input is zero. At point F the input signal again drops to -100 volts. Instantaneously the output voltage across R goes to -10 volts (input minus e_C). The diode conducts quickly, returning the charge on the condensor to 100 volts and the output to zero. These results are shown in Fig. 15. Note that no portion of the waveform is lost after the first cycle. The function of the clamping circuit is merely to shift the reference voltage from the top of the waveform to the bottom.

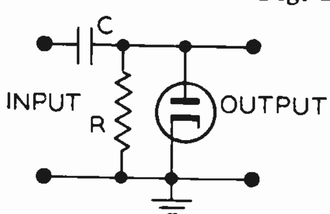


Fig. 26.

Fig. 26 illustrates a diode-clamping circuit capable of causing the output waveform to vary between some negative value and zero reference voltage. The only difference between this circuit and the one shown in Fig. 21 is in the manner in which the diode is connected. In this case the plate is connected to the output terminal while the cathode is grounded. Therefore, in this condition the tube conducts whenever the plate rises above ground.

The input signal (Fig. 22) is now applied to this negative clamping

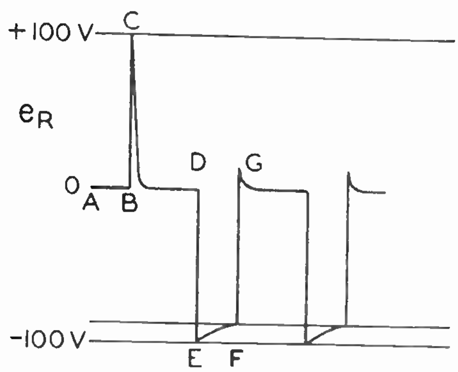


Fig. 27.

circuit. When the input is at point A the plate of the diode becomes positive and the capacitor quickly charges up to 50 volts through the short R-C path. When this occurs the output voltage drops to zero. Then at point B the input voltage suddenly rises 100 volts (from 50 volts to 150 volts). Since the capacitor charge cannot change instantaneously, the 100 volt change appears across R, sending the plate of the diode to 100 volts with respect to the cathode. The capacitor again is presented with a short R-C charging path and charges very rapidly, bringing the output voltage back to zero quickly. At point D the input signal suddenly drops 100 volts, but capacitor C is charged to 150 volts and cannot change instantaneously. The 100 volt drop therefore appears across R, sending the output from zero to -100 volts. The input voltage drops from 150 volts to 50 volts and the output drops from 0 to -100 volts. During the time from E to F the capacitor can be expected to discharge a small amount through the high resistance path of R. At point G this slight loss of charge is replaced quickly as the plate of the diode goes positive momentarily. The output signal is shown in Fig. 27.

In the practical circuit the size of the resistance R is great enough to make negligible the amount of distortion of the output caused by the slight charging of the capacitor.

Grid Clamping. -- The function of clamping may be performed at the grid of an ordinary triode or pentode as well as in a diode. Any element of a vacuum tube if made positive with respect to the cathode, attracts electrons from it. On the other hand, any element made negative with respect to the cathode repels electrons and has no current flow. Thus the grid of a tube connected as shown in Fig. 28, acts as the plate of a diode and produces the same clamping action as the circuit of Fig. 26. Any tendency for the grid to go positive causes grid current to flow, charging capacitor C to the applied potential.

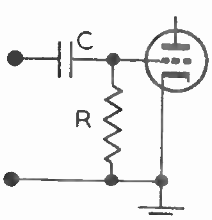


Fig. 28.

Clamping Above or Below Ground Potential. -- Although circuits previously discussed clamped one extreme of the input signal to zero potential, actual circuits need not be limited to this one reference potential. Fig. 29 illustrates the means of clamping the upper extreme of an input signal to -10 volts with respect to ground. The same principle may be applied to clamp either voltage extreme to any reference potential.

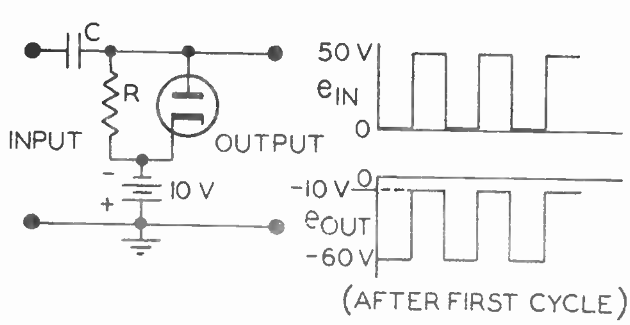


Fig. 29.

Synchronized Clamping. A more versatile clamping circuit is shown in Fig. 30. This arrangment keeps the bias on V_3 constant except for the time during which the clamping tubes V_1 and V_2 are held beyond cut-off by a synchronizing pulse. During the period of conduction of V_1 and V_2 these tubes may be considered as part of a voltage-divider network for the purpose of placing a definite voltage on the grid of V_3. Actually the circuit is slightly more complicated than the simple voltage-divider explanation would imply.

In Fig. 30, while V_2 is operating at zero (grid-to-cathode) bias and may be considered therefore as a simple resistor, V_1 is biased by the drop across V_2. The reason is that the cathode of V_1 is connected directly to the plate of V_2 and the grid of V_1 is tied directly to the grid of V_2, which in turn

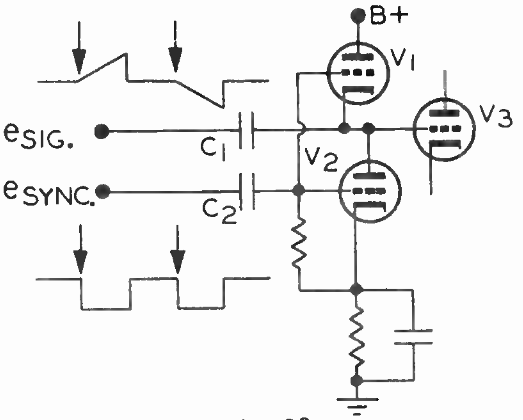


Fig. 30.

is connected effectively to the cathode of V_2, so long as no synchronizing potential is applied.

Assume that for some reason the potential at the grid of V_3 tries to rise. Except for the negligible fixed bias, which does not change, the voltage at the grid of V_3 and the voltage across V_2 are identical. Thus a rise in the grid voltage of V_3 results in an increase in the bias on V_1, which makes it a higher resistance than before, bringing the voltage at the plate of V_2 back to normal. In like manner a decrease in the voltage at the grid of V_3 means a decrease in the bias of V_1, which decreases the resistance of V_1 bringing the voltage at the grid of V_3 back to normal. So long as V_1 and V_2 conduct, the voltage at the grid of V_3 and thus the plate current of V_3 are held constant by the voltage-divider action of V_1 and V_2. V_1 is the variable resistance which controls the fraction of the B+ voltage that appears across V_2.

The synchronizing pulse is applied as a negative rectangular wave which drives V_1 and V_2 beyond cut-off for the desired length of time. With tubes V_1 and V_2 cut-off, the grid of V_3 is left free to follow any changes in input-voltage amplitude. Capacitor C_1 has no path through which to discharge except by way of the very high resistance of the insulating material used for tube bases, sockets, etc. Thus the voltage at the grid of V_3 follows exactly the input voltage. At the end of the synchronizing pulse V_1 and V_2 again conduct, returning the voltage at the grid of V_3 quickly back to the reference potential.

Application of Clamping Circuits. -- In practice, clamping usually is encountered in sweep circuits. If the sweep voltages do not always start from the same reference point, the trace itself does not begin at the same point on the screen each time the cycle is repeated, and is therefore jittery or erratic. If a clamping circuit is placed between the final sweep amplifier and the deflection element, the voltage from which the sweep signal starts can be regulated by adjusting the d.c. voltage applied to the clamping circuit. An arrangement such as that shown in Fig. 29 insures, in the case of a negative -going sweep voltage, that the waveform applied to the deflection plate varies in a negative direction from the d.c. voltage level applied to the cathode of the diode.

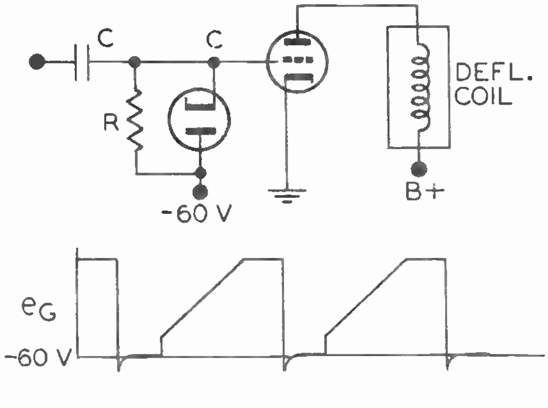


Fig. 31.

A circuit using a magnetic cathode-ray tube offers another example of sweep-clamping by the use of a diode in the grid circuit of the final sweep amplifier (Fig. 31). Such an arrangement assures that the negative extreme of the sweep waveform is clamped at the d.c. level of -60 volts. Therefore the static current, which is flowing in the final sweep-amplifier tube and in the deflection coil at the beginning of the sweep, always has the same value since the biasing voltage on the grid at this time always has the same value. Therefore, the beam always starts its trace from the same spot on the screen, because the static current in the coil at the beginning of the trace determines this position.

Clamping circuits make it possible to apply two signals, one above the trace and the other below. Without the clamping action both signals would merely vary about the sweep line and prevent an examination of their relative amplitudes.

CHAPTER IX

RADIO RULES AND REGULATIONS

PUBLIC LAW NO. 262 approved June 24, 1910 was the first law enacted pertaining to the use of radio communication equipment aboard ships. In effect this law stated that it would be unlawful for any ocean-going steamer carrying passengers and crew of more than fifty persons to leave a port of the United States unless it carried radio communication equipment in charge of a skilled operator, the apparatus being capable of transmitting and receiving messages over a distance of at least 100 miles day or night. This action did not apply to ships plying between ports less than 200 miles apart. The law also stated the fine which would be levied on any vessels violating this action. At this time the Secretary of Commerce was delegated as the enforcing agency.

The 62nd Congress amended the original radio act in July 1912. The vessels operating on the Great Lakes were included under the act and also it was specified that an auxiliary power supply should be used on all installations. It was specified that the equipment should be in charge of two or more operators, one or the other of whom should be on duty at all times that the vessel is being navigated.

Public Law 264 enacted in August of 1912 was much more specific in that it provided penalties for violations of the previous rules. The principle penalty was indicated in the following statement: "Any person, company or corporation that shall operate any apparatus for radio communication in violation of this act, shall be deemed guilty of a misdemeanor and on conviction shall be punished by a fine not exceeding 500 dollars."

This act also defined terms used in communications such as "standard distress waves", "pure wave", "sharp wave", "broad interfering wave", etc. The right of way for distress signals was indicated, inter-communication between stations belonging to different companies was made mandatory and the general restriction pertaining to private stations were thoroughly specified.

The message "secrecy" clause was made a portion of this act as well as penalties for fraudulent or false distress signals.

Unlawful interference with communications was made punishable by a fine of not to exceed 500 dollars or imprisonment for one year or both.

This act may be considered the original act which regulated the use of communication equipment on board vessels.

The administration of the laws dealing with radio communication continued to be in the hands of the Department of Commerce until the 69th Congress passed an act for the regulation of radio communications which was approved February 23, 1927. This act set up a Federal Radio Commission which consists of five members appointed by the President.

The communications networks have grown to such an extent that it became necessary to create this special commission to administer rules and regulations preventing the misuse of communications channels.

No station license shall be granted by the Commission or the Secretary of Commerce until the applicant therefor shall have signed a waiver of any claim to the use of any particular frequency or wave length or of the ether as against the regulatory power of the United States because of the previous use of the same, whether by license or otherwise.

The station license required hereby shall not be granted to, or after the granting thereof, such license shall not be transferred in any manner, either voluntarily or involuntarily, to (a) any alien or the representative of any alien (b) to any foreign government, or the representative thereof; (c) to any company, corporation, or association organized under the laws of any foreign government; (d) to any company, corporation, or association of which any officer or director is an alien, or of which more than one-fifth of the capital stock may be voted by aliens or their representatives or by a foreign government or representative thereof, or by any company, corporation, or association organized under the laws of a foreign country.

The station license required hereby, the frequencies or wave length or lengths authorized to be used by the licensee, and the rights therein granted shall not be transferred, assigned, or in any manner, either voluntarily or involuntarily, disposed of to any person, firm, company, or corporation without the consent in writing of the licensing authority.

If any licensee shall permit any person who is legally qualified candiate for any public office to use a broadcasting station, he shall afford equal opportunities to all other such candidates for that office in the use of such broadcasting station, and the licensing authority shall make rules and regulations to carry this provision into effect: PROVIDED, that such licensee shall have no power of censorship over the material broadcast under the provisions of this paragraph. No obligation is hereby imposed upon any licensee to allow the use of its station by any such candidate.

The actual operation of all transmitting apparatus in any radio station for which a station license is required by this act shall be carried on only by a person holding an operator's license issued hereunder. No person shall operate any such apparatus in such station except under and in accordance with an operator's license issued to him by the Secretary of Commerce.

No license shall be issued under the authority of this act for the operation of any station the construction of which is begun or is continued after this Act takes effect, unless a permit for its construction has been granted by the licensing authority upon written application therefor. The licensing authority may grant such permit if public convenience, interest, or necessity will be served by the construction of the station. This application shall set forth such facts as the licensing authority by the regulation may prescribe as to the citizenship, character, and the financial, technical, and other ability of the applicant to construct and operate the station, the ownership and location of the proposed station and of the station or stations with which it is proposed to communicate, the frequencies and wave length or wave lengths desired to be used, the hours of the day, or other periods of time during which it is proposed to operate the station, the purpose for which the station is to be used, the type of transmitting apparatus to be used, the power to be used, the date upon which the station is expected to be completed and in operation, and such other information as the licensing authority may require. Such application shall be signed by the applicant under oath or affirmation.

Such permit for construction shall show specifically the earliest and latest dates between which the actual operation of such station is expected to begin, and shall provide that said permit will be automatically forfeited if the station is not ready for operation within the time specified or within such further time as the licensing authority may allow, unless prevented by causes not under the control of the grantee. The rights under any such permit shall not be assigned or otherwise transferred to any person, firm, company, or corporation without the approval of the licensing authority. A permit for construction shall not be required for government stations, amateur stations, or stations upon mobile vessels, railroad rolling stock, or aircraft. Upon the completion of any station for the construction or continued construction for which a permit has been granted, and upon it being made to appear to the licensing authority that all the terms, conditions, and obligations set forth in the application and permit have been fully met, and that no cause or circumstance arising or first coming to the knowledge of the licensing authority since the granting of the permit would, in the judgement of the licensing authority, make the operation of such station against the public interest, the licensing authority shall issue a license to the lawful holder of said permit for the operation of said station. Said license shall conform generally to the terms of said permit.

Every radio station on shipboard shall be equipped to transmit radio communications or signals of distress on the frequency or wave length specified by the licensing authority, with apparatus capable of transmitting and receiving messages over a distance of a least one hundred miles by day or night. When sending radio communications or signals of distress and radio communications relating thereto the transmitting set may be adjusted in such a manner as to produce a maximum of radiation irrespective of the amount of interference which may thus be caused.

All radio stations, including Government stations and stations on board foreign vessels when within the territorial waters of the United States, shall give absolute priority to radio communications or signals relating to ships in distress; shall cease all sending on frequencies or wave lengths which will interfere with hearing a radio communication or signal of distress, and, except when engaged in answering or aiding the ship in distress, shall refrain from sending any radio communications or signals until there is assurance that no interference will be caused with the radio communications or signals relating thereto, and shall assist the vessel in distress so far as possible, by complying with its instructions.

Every shore station open to general public service between the coast and vessels at sea shall be bound to exchange radio communications or signals with any ship station without distinction as to radio systems or instruments adopted by such stations, respectively, and each station on shipboard shall be bound to exchange radio communications or signals with any other station on shipboard without distinction as to radio systems or instruments adopted by each station.

In all circumstances, except in case of radio communications or signals relating to vessels in distress, all radio stations, including those owned and operated by the United States, shall use the minimum amount of power necessary to carry out the communication desired.

No person receiving or assisting in receiving any radio communication shall divulge or publish the contents, substances, purport, effect, or meaning thereof except through authorized channels of transmission or reception to any person other than the addressee, his agent, or attorney, or to a telephone, telegraph, cable, or radio station employed or authorized to forward such radio communication to its destination, or to proper accounting or distributing officers of the various communicating centers over which the radio communication may be passed, or to the master of a ship under whom he is serving, or in response to a subponea issued by a court of competent jurisdiction, or on demand of other lawful authority; and no person not being authorized by the sender shall intercept any message and divulge or publish the contents, substance, purport, effect, or meaning of such intercepted message to any person; and no person not being entitled thereto shall receive or assist in receiving any radio communication and use the same or any information therein contained for his own benefit or for the benefit of another not entitled thereto; and no person having received such intercepted radio communication or having become acquainted with the contents, substance, purport, effect, or meaning of the same or any part thereof, knowing that such information was so obtained, shall divulge or publish the contents, substance, purport, effect or meaning of the same or any part thereof, or use the same or any information therein contained for his own benefit or for the benefit of another not entitled thereto: PROVIDED, that this section shall not apply to the receiving, divulging, publishing or utilizing the contents of any radio communication broadcasted or transmitted by amateurs or others for the use of the general public or relating to ships in distress.

No person, firm company, or corporation within the jurisdiction of the United States shall knowingly utter or transmit, or cause to be uttered or transmitted, any false or fraudulent signal of distress, or communication relating thereto, nor shall any broadcasting station rebroadcast the program or any part thereof of another broadcasting station without the express authority of the originating station.

Nothing in this Act shall be understood or construed to give the licensing authority the power of censorship over the radio communications or signals transmitted by any radio station and no regulation or condition shall be promulgated or fixed by the licensing authority which shall interfere with the right of free speech by means of radio communications. No person within the jurisdiction of the United States shall utter any obscene, indecent, or profane language by means of radio communication.

Any person, firm, company or corporation who shall violate any provision of this Act, or shall knowingly make any false oath or affirmation in any affidavit required or authorized by the Act, or shall knowingly swear falsely to a material matter in any hearing authorized by this Act, upon conviction thereof in any court of competent jurisdiction shall be punished by a fine of not more than 5000 dollars or by imprisonment for a term of not more than five years or both for each and every such offense.

PUBLIC LAW NO. 254 - 72nd Congress, July 5, 1932 - To regulate radio equipment on ocean-going vessels using the ports of the Canal Zone.

That it shall be unlawful for any ocean-going vessel carrying fifty or more persons, including passengers and crew, to leave or attempt to leave any port of the Canal Zone unless such vessel shall be equipped with an efficient apparatus for radio communication, in good working order, in charge of a person skilled in the use of such apparatus, which apparatus shall be capable of transmitting and receiving messages for a distance of at least one hundred miles, night or day. This requirement shall not apply to vessels merely transiting the Canal or to vessels plying between Canal Zone ports and ports less than two hundred miles therefrom.

That any vessel leaving or attempting to leave a Canal Zone port not equipped as required by section 1 of this Act shall be liable to a fine not to exceed 5000 dollars and each such departure or attempted departure shall constitute a separate offense. Fines shall be recovered in the district court of the Canal Zone, and the amount so recovered shall be a lien upon such vessel, and it may be seized and sold to satisfy same, as well as all cost of the court proceedings.

PUBLIC LAW NO. 416 - 73rd Congress - Title 1 - General Provisions - Purposes of Act; Creation of Federal Communications Commission.

For the purpose of regulating interstate and foreign commerce in communication by wire and radio so as to make available, so far as possible, to all the people of the United States a rapid, efficient, Nation-wide, and world-wide wire and radio communication service with adequate facilities at reasonable charges, for the purpose of the national defense, and for the purpose of securing a more effective execution of this policy by centralizing authority heretofore granted by law to several agencies and by granting additional authority with respect to interstate and foreign commerce in wire and radio communication, there is hereby created a commission to be known as the "Federal Communications Commission", which shall be constituted as hereinafter provided, and which shall execute and enforce the provisions of this Act.

DEFINITIONS

For the purposes of the Act, unless the context otherwise requires - (a) "Wire communication" or "communication by wire" means the transmission of writing, signs, signals, pictures, and sounds of all kinds by aid of wire, cable, or other like connection between the points of origin and reception of such transmission including all instrumentalities, facilities, apparatus, and services (among other things, the receipt, forwarding, and delivery of communications) incidental to such transmission.

(b) "Radio communication" or communication by radio" means the transmission by radio of writing, signs, signals, pictures, and sounds of all kinds, including all instrumentalities, facilities, apparatus, and services (among other things, the receipt, forwarding, and delivery of communications) incidental to such transmission.

(c) "Licensee" means the holder of a radio station license granted or continued in force under authority of this Act.

(d) "Transmission of energy by radio" or "radio transmission of energy" includes both such transmission and all instrumentalities, facilities, and services incidental to such transmission.

(e) "Interstate communication" or "interstate transmission" means communication or transmission (1) from any State, Territory, or possession of the United States (other than the Philippine Islands and the Canal Zone), or the District of Columbia, to any other State, Territory, or possession of the United States (other than the Philippine Islands and the Canal Zone), or the District of Columbia, (2) from or to the United States to or from the Philippine Islands or the Canal Zone, insofar as such communication or transmission takes place within the United States, or (3) between points within the United States but through a foreign country; but shall not include wire communication between points within the same State, Territory, or possession of the United States, or the District of Columbia, through any place outside thereof, if such communication is regulated by a State commission

(f) "Foreign communication" or "foreign transmission" means communication or transmission from or to any place in the United States to or from a foreign country, or between a station in the United States and mobile station located outside the United States.

(g) "United States" means the several States and Territories, the District of Columbia, and the possessions of the United States, but does not include the Philippine Islands or the Canal Zone.

(h) "Common carrier" or " carrier " means any person engaged as a common carrier for hire, in interstate or foreign communication by wire or radio or in interstate or foreign radio transmission of energy, except where reference is made to common carriers not subject to this act; but a person engaged in radio broadcasting shall not, insofar as such person is so engaged, be deemed a common carrier.

(i) "Person" includes an individual, partnership, association, joint-stock company, trust, or corporation.

(j) "Corporation" includes any corporation, joint-stock company, or association

(k) "Radio station" or "Station" means a station equipped to engage in radio communication or radio transmission of energy.

(l). "Mobile station" means a radio-communication station capable of being moved and which ordinarily does move.

(m) "Land Station" means a station, other than a mobile station used for radio communication with mobile stations.

(n) "Mobile service" means the radio-communication service carried on between mobile stations and land stations, and by mobile stations communicating among themselves.

(o) "Broadcasting" means the dissemination of radio communications intended to be received by the public, directly or by the intermediary of relay stations.

(p) "Chain broadcasting" means simultaneous broadcasting of an identical program by two or more connected stations.

(q) "Amateur station" means a radio station operated by a duly authorized person interested in radio techinque solely with a personal aim and without pecuniary interest.

(r) "Telephone exchange service" means service within a telephone exchange, or within a connected system of telephone exchanges within the same exchange area operated to furnish to subscribers intercommunicating service of the character ordinarily furnished by a single exchange, and which is covered by the exchange service charge.

(s) "Telephone toll service" means telephone service between stations in different exchange areas for which there is made a separate charge not included in contracts with subscribers for exchange service.

(t) "State commission means the commission, board, or official (by whatever name designated) which under the laws of any State, has regulatory jurisdiction with respect to intrastate operations of carriers.

(u) "Connecting carrier" means a carrier described in clause (2) of section 2(b).

(v) "State" includes the District of Columbia and the Territories and possessions.

ANNUAL AND OTHER REPORTS

The Commission is authorized to require annual reports under oath from all carriers subject to this Act, and from persons directly or indirectly controlling or controlled by, or under direct or indirect common control with, and such carrier, to prescribe the manner in which such reports shall be made, and to require from such persons specific answers to all questions upon which the Commission may need information.

GENERAL POWERS OF COMMISSION

Except as otherwise provided in this Act, the Commission from time to time, as public convenience, interest, or necessity requires, shall

(a) Classify radio stations;

(b) Prescribe the nature of the service to be rendered by each class of licensed stations and each station within any class;

(c) Assign bands of frequencies to the various classes of stations, and assign frequencies for each individual station and determine the power which each station shall use and the time during which it may operate;

(d) Determine the location of classes of stations or individual stations:

(e) Regulate the kind of apparatus to be used with respect to its external effects and the purity and sharpness of the emissions from each station and from the apparatus therein;

(f) Make such regulations not inconsistent with law as it may deem necessary to prevent interference between stations and to carry out the provisions of this Act: Provided, however, that changes in the frequencies, authorized power, or in the times of operation of any station, shall not be made without the consent of the station licensee unless, after a public hearing, the Commission shall determine that such changes will promote public convenience or interest or will serve the public necessity, or the provisions of the Act will be more fully complied with.

(g) Study new uses for radio, provide for experimental uses of frequencies, and generally encourage the larger and more effective use of radio in the public interest;

(h) Have authority to extablish areas or zones to be served by any station

(i) Have authority to make special regulations applicable to radio stations engaged in chain broadcasting,

(j) Have authority to make general rules and regulations requiring stations to keep such records of programs, transmissions of energy, communications, or signals as it may deem desirable;

(k) Have authority to exclude from the requirments of any regulations in whole or in part any radio station upon railroad rolling stock, or to modify such regulations in its discretion;

(l) Have authority to prescribe the qualifications of station operators, to classify them according to the duties to be performed, to fix the forms of such licenses, and to issue them to such citizens of the United States as the Commission finds qualified;

(m) Have authority to suspend the license of any operator for a period not exceeding two years upon proof sufficient to satisfy the Commission that the licensee (1) has violated any provision of any Act or treaty binding on the United States which the Commission is authorized by this Act to administer or any regulation made by the Commission under any such Act or treaty; or (2) has failed to carry out the lawful orders of the master of the vessel on which he is employed: or (3) has willfully damaged or permitted radio apparatus to be damaged; or (4) has transmitted superfluous radio communications or signals or radio communications containing profane or obscene words or language; or (5) has willfully or maliciously interfered with any other radio communications or signals;

(n) Have authority to inspect all transmitting apparatus to ascertain whether in construction and operation it conforms to the requirements of this Act, the rules and regulations of the regulations of the Commission, and the license under which it is constructed and operated;

(o) Have authority to designate call letters of all stations;

(p) Have authority to cause to be published such call letters and such other announcements and data as in the judgment of the Commission may be required for the efficient operation of radio stations subject to the jurisdiction of the United States and for proper enforcement of this Act;

(q) Have authority to require the painting and/or illumination of radio towers if and when in its judgment such towers constitute, or there is a reasonable possibility that they may constitute, a menace to air navigation.

ALLOCATION OF FACILITIES; TERM OF LICENSES

(a) It is hereby declared that the people of all the zones established by this title are entitled to equality of radio broadcasting service, both of transmission and of reception, and in order to provide said equality the Commission shall as nearly as possible make and maintain an equal allocation of broadcasting licenses, of bands of frequency, of periods of time for operation and of station power, to each of said zones when and insofar as there are applications therefor; and shall make a fair and equitable allocation of licenses, frequencies, time for operation, and station power to each of the States and District of Columbia, within each zone, according to population. The Commission shall carry into effect the equality of broadcasting service hereinbefore directed, whenever necessary or proper, by granting or refusing license or renewals of licenses, by changing periods of time for operation, and by increasing or decreasing station power, when applications are made for licenses or renewals of licenses: Provided, That if and when there is a lack of applications from any zone for the proportionate share of licenses, frequencies, time of operation, or station power to which such zone is entitled, the Commission may issue licenses for the balance of the proportion not applied for from any zone, to applicants from other zones for a temporary period of ninety days each, and shall specifically designate that said apportionment is only for said temporary period. Allocations shall be charged to the State or District wherein the studio of the station is located: Provided further, That the Commission may also grant applications for additional licenses for stations not exceeding one hundred watts of power if the Commission finds that such stations will serve the public convenience, interest, or necessity, and that their operation will not interfere with the fair and efficient radio service of stations licensed under the provisions of this section.

(b) No license granted for the operation of a broadcasting station shall be for a longer term than three years and no license so granted for any other class of station shall be for a longer term than five years, and any license granted may be revoked as hereinafter provided. Upon the expiration of any license, upon application therefor, a renewal of such license may be granted from time to time for a term of not to exceed three years in the case of broadcasting licenses and not to exceed five years in the case of other licenses, but action of the Commission with reference to the granting of such application for the renewal of a license shall be limited to and governed by the same considerations and practive which affect the granting of original applications.

LIMITATION ON HOLDING AND TRANSFER OF LICENSES

(a) The station license required hereby shall not be granted to or held by -
  (1) Any alien or the representative of any alien;
  (2) Any foreign government or the representative thereof;
  (3) Any corporation organized under the laws of any foreign government;
  (4) Any corporation of which any officer or director is an alien or of which more than one-fifth of the capital stock is owned of record or voted by aliens or their representatives or by a foreign government or representative thereof, or by any corporation organized under the laws of a foreign country;
  (5) Any corporation directly or indirectly controlled by any other corporation of which any officer or more than one-fourth of the directors are aliens, or of which more than one-fourth of the capital stock is owned of record or voted, after June 1, 1935, by aliens, their representatives or by a foreign government or representative thereof, or by any corporation organized under the laws of a foreign country, if the Commission finds that the public interest will be served by the refusal or the revocation of such license.

Nothing in this subsection shall prevent the licensing of radio apparatus on board any vessel, aircraft, or other mobile station of the United States when the installation and use of such apparatus is required by Act of Congress or any treaty to which the United states is a party.

(b) The station license required hereby, the frequencies authorized to be used by the licensee, and the rights therein granted shall not be transferred, assigned, or in any manner either voluntarily or involuntarily disposed of, or indirectly by transfer of control of any corporation holding such license, to any person, unless the Commission shall, after securing full information, decide that said transfer is in the public interest, and shall give its consent in writing.

REFUSAL OF LICENSES AND PERMITS IN CERTAIN CASES

The Commission is hereby directed to refuse a station license and/or the permit hereinafter required for the construction of a station to any person (or to any person directly or indirectly controlled by such person) whose license has been revoked by a court under section 313, and is hereby authorized to refuse such station license and/or permit to any other person directly or indirectly controlled by such person which has been finally adjudged guilty by a Federal court of unlawfully monopolizing or attempting unlawfully to monopolize, radio communication, directly or indirectly, through the control of the manufacture or sale of radio apparatus, through exclusive traffic arrangements, or by any other means, or to have been using unfair methods of competition. The granting of a license shall not stop the United States or any person aggrieving from proceeding against such person for violating the law against unfair methods of competition or for a violation of the law against unlawful restraints and monopolies and/or combinations contracts, or agreements in restraint of trade, or from instituting proceedings for the dissolution of such corporation.

REVOCATION OF LICENSES

(a) Any station license may be revoked for false statements either in the application or in the statement of fact which may be required by section 308 hereof, or because of conditions revealed by such statements of fact as may be required from time to time which would warrent the Commission in refusing to grant a license or an original application, or for failure to operate substantially as set forth in the license, or for violation of or failure to observe any of the restrictions and conditions of this Act or of any regulations of the Commission authorized by this Act or by a treaty ratified by the United States.

FACILITIES FOR CANDIDATES FOR PUBLIC OFFICE

If any licensee shall permit any person who is a legally qualified candidate for any public office to use a broadcasting station, he shall afford equal opportunities to all other such candidates for that office in the use of such broadcasting station, and the Commission shall make rules and regulations to carry this provision into effect: Provided, That such licensee shall have no power of censorship over the material broadcast under the provisions of this section. No obligation is hereby imposed upon any licensee to allow the use of its station by any such candidate.

OPERATION OF TRANSMITTING APPARATUS

The actual operation of all transmitting apparatus in any radio station for which a station license is required by this Act shall be carried on only by a person holding an operator's license issued hereunder. No person shall operate any such apparatus in such station except under and in accordance with an operator's license issued to him by the Commission.

CONSTRUCTION PERMITS

(a) No license shall be issued under the authority of this Act for the operation of any station the construction of which is begun or is continued after this Act takes effect, unless a permit for its construction has been granted by the Commission upon written application therefor. The Commission may grant such permit if public convenience, interest, or necessity will be served by the construction of the station. This application shall set forth such facts as the Commission by regulation may prescribe as to the citizenship, character, and the financial, technical, and other ability of the applicant to construct and operate the station, the ownership and location of the proposed station and of the station or stations with which it is proposed to communicate, the frequencies desired to be used, the hours of the day or other periods of time during which it is proposed to operate the station, the purpose for which the station is to be used, the type of transmitting apparatus to be used, the power to be used, the date upon which the station is expected to be completed and in operation, and such other information as the Commission may require. Such application shall be signed by the applicant under oath or affirmation.

DISTRESS SIGNALS AND COMMUNICATIONS

(a) Every radio station on shipboard shall be equipped to transmit radio communications or signals of distress on the frequency specified by the Commission, with apparatus capable of transmitting and receiving messages over a distance of at least one hundred miles by day or night. When sending radio communications or signals of distress and radio communications relating thereto the transmitting set may be adjusted in such a manner as to produce a maximum of radiation irrespective of the amount of interference which may thus be caused.

(b) All radio stations, including Government stations and stations on board foreign vessels when within the territorial waters of the United States, shall give absolute priority to radio communications or signals relating to ships in distress; shall cease all sending on frequencies which will interfere with hearing a radio communication or signal of distress, and except when engaged in answering or aiding a ship in distress, shall refrain from sending any radio communications or signals until there is assurance that no interference will be caused with the radio communications or signals relating thereto, and shall assist the vessel in distress so far as possible, by complying with its instructions.

INTERCOMMUNICATION IN MOBILE SERVICE

Every land station open to general public service between the coast and vessels at sea shall be bound to exchange radio communications or signals with any ship station without distinction as to radio systems or instruments adopted by such stations, respectively, and each station on shipboard shall be bound to exchange radio communications or signals with any other station on shipboard without distinction as to radio systems or instruments adopted by each station.

USE OF MINIMUM POWER

In all circumstances, except in case of radio communications or signals relating to vessels in distress, all radio stations, including those owned and operated by the United States, shall use the minimum amount of power necessary to carry out the communication desired.

FALSE DISTRESS SIGNALS; REBROADCASTING

No person within the jurisdiction of the United States shall knowingly utter or transmit, or cause to be uttered or transmitted, any false or fraudulent signal of distress, or communication relating thereto, nor shall any broadcasting station rebroadcast the program or any part thereof of another broadcasting station without the express authority of the originating station.

CENSORSHIP; INDECENT LANGUAGE

Nothing in this Act shall be understood or construed to give the Commission the power of censorship over the radio communications or signals transmitted by any radio station, and no regulation or condition shall be promulgated or fixed by the Commission which shall interfere with the right of free speech by means of radio communication. No person within the jurisdiction of the United States shall utter any obscene, indecent, or profane language by means of radio communication.

PENAL PROVISIONS - FORFEITURES

GENERAL PENALTY

Any person who willfully and knowingly does or causes or suffers to be done any act, matter, or thing, in this Act prohibited or declared to be unlawful, or who willfully and knowingly omits or fails to do any act, matter, or thing, or thing in this Act required to be done, or willfully and knowingly causes or suffers such omission or failure, shall, upon conviction thereof, be punished for such offense, for which no penalty (other than a forfeiture) is provided herein, by a fine of not more than 10,000 dollars or by imprisonment for a term of not more than two years, or both.

VIOLATIONS OF RULES, REGULATIONS, AND SO FORTH

Any person who willfully and knowingly violates any rule, regulation, restriction, or condition made or imposed by the Commission under authority of this Act, or any rule regulation, restriction, or condition made or imposed by any international radio or wire communications treaty or convention, or regulations annexed thereto, to which the United States is or may hereafter become a party, shall, in addition to any other penalties provided by law, be punished, upon conviction thereof, by a fine of not more than 500 dollars for each and every day during which such offense occurs.

UNAUTHORIZED PUBLICATION OF COMMUNICATIONS

No person receiving or assisting in receiving, or transmitting, or assisting in transmitting, any interstate or foreign communication by wire or radio shall divulge or publish the existence, contents, substance, purport, effect, or meaning thereof, except through authorized channels of transmission or reception to any person other than the addressee, his agent, or attorney, or to a person employed or authorized to forward such communication to its destination, or to proper accounting or distributing officers of the various communicating centers over which the communication may be passed, or to the master of a ship under whom he is serving or in response to a subpena issued by a court of competent jurisdiction, or on demand of other lawful authority; and no person not being authorized by the sender shall intercept any communication and divulge or publish the existence, contents, substance, purport, effect, or meaning of such intercepted communication to any person; and no person not being entitled thereto shall receive or assist in receiving any interstate or foreign communication by wire or radio and use the same or any information therein contained for his own benefit or for the benefit of another not entitled thereto; and no person having received such intercepted communication or having become acquainted with the contents, substance, purport, effect, or meaning of the same or any part thereof, knowing that such information was so obtained, shall divulge or publish the existence, contents, substance, purport effect or meaning of the same or any part thereof, or use the same or any information therein contained for his own benefit or for the benefit of another not entitled thereto: Provided, That this section shall not apply to the receiving,divulging, publishing, or utilizing the contents of any radio communication broadcast, or transmitted by amateurs or others for the use of the general public or relating to ships in distress.

WAR EMERGENCY - POWERS OF PRESIDENT

During the continuance of a war in which the United States is engaged, the President is authorized, if he finds it necessary for the national defense and security, to direct that such communications as in his judgement may be essential to the national defense and security shall have preference or priority with any carrier subject to this Act.

PUBLIC LAW NO. 97 - 75th Congress - Section 3 of the Communications Act of 1934 is hereby amended by adding at the end thereof five new subsections to read as follows:

(w) (1) 'Ship' or 'vessel' includes every description of watercraft or other artificial contrivance, except aircraft, used or capable of being used as a means of transportation on water, whether or not it is actually afloat.

(2) A ship shall be considered a passenger ship if it carries or is licensed or certificated to carry more than twelve passengers.

(3) A cargo ship means any ship not a passenger ship.

(4) A passenger is any person carried on board a ship or vessel except (1) the officers and crew actually employed to man and operate the ship (2) persons employed to carry on the business of the ship, and (3) persons on board a ship when they are carried, either because of the obligation laid upon the master to carry shipwrecked, distressed, or other persons in like or similar situations or by reason of any circumstance over which neither the master, the owner, nor the charterer (if any) has control.

(x) 'Auto-alarm' on a foreign ship means an automatic alarm receiver which has been approved by the country to which the ship belongs, provided the United States and the country to which the ship belongs are both parties to the same treaty, convention, or agreement prescribing the requirements for such apparatus. 'Auto-alarm' on a ship of the United States subject to the provisions of Part II of title III of this Act means an automatic alarm receiver complying with law and approved by the Commission. Nothing in this Act or in any other provision of law shall be construed to require the recognition of an auto-alarm as complying with part II of title III of this Act, on a foreign ship subject to such part, whose country of origin is not a party to a treaty, convention, or agreement with the United States in regard to such apparatus.

(y) (1) For the purpose of part II of title III, a 'qualified operator' or 'operator' on a foreign ship means a person holding a certificate such complying with the provisions of the General Radio Regulations annexed to the International Telecommunication Convention in force, or complying with an agreement or treaty between the United States and the country to which the ship belongs.

(2) For the purpose of part II of title III, a 'qualified operator' or 'operator' on a ship of the United States means a person holding a radio operator's license of the proper class, as precribed and issued by the Commission.

(z) 'Harbor' or 'port' means any place to which ships may resort for shelter or to load or unload passengers or goods, or to obtain fuel, water or supplies. This term shall apply to such places whether proclaimed public or not and whether natural or artificial.

(aa) 'Safety convention' means the International Convention for the Safety of life at sea in force and the regulations referred to therein.

Paragraph (m) of section 303 of the Communications Act of 1934 is hereby amended to read as follows:

(m) (1) Have authority to suspend the license of any operator upon proof sufficient to satisfy the Commission that the licensee -

(A) has violated any provision of any Act, treaty, or convention binding on the United States, which the Commission is authorized to administer, or any regulation made by the Commission under any such Act, treaty, or convention; or

(B) has failed to carry out a lawful order of the master or person lawfully in charge of the ship or aircraft on which he is employed; or

(C) has willfully damaged or permitted radio apparatus or installations to be damaged; or

(D) has transmitted superfluous radio communications or signals or communications containing profane or obscene words, language, or meaning, or has knowingly transmitted -

(1) false or deceptive signals or communications, or

(2) a call signal or letter which has not been assigned by proper authority to the station he is operating; or

(E) has willfully or maliciously interfered with any other radio communications or signals; or

(F) has obtained or attempted to obtain, or has assisted another to obtain or attempt to obtain, and operators license by fraudulent means.

(2) No order of suspension of any operator's license shall take effect until fifteen days notice in writing thereof, stating the cause for the proposed suspension, has been given to the operator licensee who may make written application to the Commission at any time within said fifteen days for a hearing upon such order. The notice to the operator licensee shall not be effective until actually received by him, and from that time he shall have fifteen days in which to mail the said application. In the event that physical conditions prevent mailing of the application at the expiration of the fifteen day period, the application shall then be mailed as soon as possible thereafter, accompanied by a satisfactory explanation of the delay. Upon receipt by the Commission of such application for hearing said order of suspension shall be held in abeyance until the conclusion of the hearing which shall be conducted under such rules as the Commission may prescribe. Upon the conclusion of said hearing the Commission may affirm, modify, or revoke said order of suspension.

(a) Subsection (n) of Section 303 of the Communications Act of 1934 is hereby amended to read as follows:

(n) Have authority to inspect all radio installations associated with stations required to be licensed by any Act or which are subject to the provisions of any Act, treaty, or convention binding on the United States, to ascertain whether in construction, installation, and operation they conform to the requirements of the rules and regulations of the Commission, the provisions of any Act, the terms of any treaty or convention binding on the United States, and the conditions of the license or other instrument of authorization under which they are constructed, installed, or operated.

(b) Section 303 of the Communications Act of 1934 is hereby further amended by adding at the end thereof a new subsection to read as follows:

(r) Make such rules and regulations and prescribe such restrictions and conditions, not inconsistent with law, as may be necessary to carry out the provisions of this Act, or any international radio or wire communications treaty or convention or regulations annexed thereto, including any treaty or convention insofar as it relates to the use of radio, to which the United States is or may hereafter become a party.

(a) of the Communications Act of 1934 is hereby amended to read as follows:

(a) The transmitting set in a radio station on shipboard may be adjusted in such a manner as to produce a maximum of radiation, irrespective of the amount of interference which may thus be caused, when such station is sending radio communications or signals of distress and radio communications relating thereto.

Section 322 of the Communications Act of 1934 is hereby amended to read as follows

Every land station open to general public service between the coast and vessels or aircraft at sea shall, within the scope of its normal operations, be bound to exchange radio communications or signals with any ship or aircraft station at sea; and each station on shipboard or aircraft at sea shall, within the scope of it normal operations, be bound to exchange radio communications or signals with any other station on shipboard or aircraft at sea or with any land station open to general public service between the coast and vessels or aircraft at sea: Provided, That such exchange of radio communication shall be without distinction as to radio systems or instruments adopted by each station.

TITLE III - PROVISIONS RELATING TO RADIO

Part I - GENERAL PROVISIONS

(b) Such title III is further amended by adding at the end thereof a new part as follows:

Part II - RADIO EQUIPMENT AND RADIO OPERATORS ON BOARD SHIP

SHIP RADIO INSTALLATIONS AND OPERATIONS

(a) Except as provided in section 352 hereof, it shall be unlawful -

(1) For any ship of the United States, other than a cargo ship of less than sixteen hundred gross tons, to be navigated in the open sea outside of a harbor or port, or for any ship of the United States or any foreign country, other than a cargo ship of less than sixteen hundred gross tons, to leave or attempt to leave any harbor or port of the United States for a voyage in the open sea, unless such ship is equipped with an efficient radio installation in operating condition, in charge and operated by a qualified operator or operators, adequately installed and protected so as to insure proper operation, and so as not to endanger the ship and radio installations, as hereinafter provided, and in the case of a ship of the United States unless there is on board a valid station license issued in accordance with this Act;

(2) For any passenger ship of the United States of five thousand gross tons,or over, to be navigated outside of a harbor or port, in the open sea, or for any such ship of the United States or any foreign country to leave or attempt to leave any harbor or port of the United States for a voyage in the open sea, unless such ship is equipped with an efficient radio direction finder apparatus (radio compass) properly adjusted in operating condition as hereinafter provided, which apparatus is approved by the Commission;

(b) A ship which is notsubjectto the provisions of this part at the time of its departure on a voyage shall not become subject to such provisions on account of any deviation from its intended voyage due to stress of weather or any other cause over which neither the master, the owner, nor the charter (if any) has control.

EXCEPTIONS

(a) The provisions of this part shall not apply to -

(1) A ship of war;

(2) A ship of the United States belonging to and operated by the government, except a ship of the United States Maritime Commission, the Inland and Coastwise Waterways Service or the Panama Railroad Company;

(3) A foreign ship belonging to a country which is a party to the Safety Convention and which ship carries a valid certificate exempting said ship from the radio provisions of the Convention, or which ship conforms to the radio requirements of such Convention or Regulations and has on board a valid certificate to that effect;

(4) Yachts of less than six hundred gross tons not subject to the radio provisions of the Safety Convention;

(5) Vessels in tow;

(6) A vessel navigating solely on the Great Lakes, or on any bays, sounds, rivers, or protected waters within the jurisdiction of the United States, or to a vessel leaving or attempting to leave any harbor or port in the United States for a voyage solely on the Great Lakes, or on bays, sounds, rivers, or protected waters within the jurisdiction of the United States, or to a vessel leaving or attempting to leave any harbor or port of the United States for a voyage solely on the Great Lakes, or on any bays, sounds, rivers, or protected waters within the jurisdiction of the United States.

(b) The Commission may if it considers that the route or the conditions of the voyage or other circumstances are such as to render a radio installation unreasonable or unnecessary for the purposes of this part, exempt from the provisions of this part any ship, or any class of ships, which falls within any of the following descriptions:

(1) Passenger ships which in the course of their voyage do not go more than twenty nautical miles from the nearest land or more than two hundred nautical miles between two consecutive ports;

(2) Cargo ships which in the course of their voyage do not go more than one hundred and fifty nautical miles from the nearest land;

(3) Passenger vessels of less than one hundred gross tons not subject to the radio provisions of the Safety Convention;

(4) Sailing ships.

OPERATORS, WATCHES, AUTO-ALARM

(a) Each cargo ship required by this part to be fitted with a radio installation and which is not fitted with an auto-alarm, and each passenger ship required by this part to be fitted with a radio installation, shall, for safety purposes, carry at least two qualified operators.

(b) A cargo ship, required by this part to be fitted with a radio installation, which is fitted with an auto-alarm in accordance with this title, shall, for safety purposes, carry at least one qualified operator who shall have had at least six months previous service in the aggregate as a qualified operator in a station on board a ship or ships of the United States.

(c) Each ship of the United States required by this part to be fitted with a radio installation shall, while being navigated outside a harbor or port, keep a continuous watch by of qualified operators: Provided, however, That in lieu thereof on a cargo ship fitted with an auto-alarm in proper operating condition, a watch of at least eight hours per day, in the aggregate, shall be maintained by means of a qualified operator.

(d) The Commission shall, when it finds it necessary for safety purposes have authority to prescribe the particular hours of watch on a ship of the United States required by this part to be fitted with a radio installation.

(e) On all ships of the United States fitted with an auto-alarm, said apparatus shall be in operation at all times while the ship is being navigated outside of a harbor or port when the operator is not on watch.

TECHNICAL REQUIREMENTS

The radio installation and the radio direction-finding apparatus required by section 351 of this part shall comply with the following requirements:

(a) The radio installation shall comprise a main and an emergency or reserve installation: Provided, however, That on a cargo ship, if the main installation complies also with all the requirements of an emergency or reserve installation, the emergency or reserve installation may be omitted.

(b) The ship's radio operating room and the emergency or reserve installation shall be placed in the upper part of the ship in a position of the greatest possible safety and as high as practicable above the deepest load water line, and the location of such room or rooms shall be approved by the Bureau of Marine Inspection and Navigation, Department of Commerce.

(c) The main and emergency or reserve installations shall be capable of transmitting and receiving on the frequencies and types of waves designated by the Commission pursuant to law for the purpose of distress and safety of navigation.

(d) The main installation shall have a normal transmitting and receiving range of at least two hundred nautical miles, that is to say, it must be capable of transmitting and receiving clearly perceptible signals from ship to ship over a range of at least two hundred nautical miles by day under normal conditions and circumstances.

(e) Sufficient power shall be available at all times to operate the main radio installation efficiently under normal conditions over the range specified in subsection (d) of this section.

(f) The emergency or reserve installation shall include a source of energy independent of the propelling power of the ship and of any other electrical system and shall be capable of being put into operation rapidly and of working for at least six continuous hours. For the emergency or reserve installation, the normal range as defined in subsection (d) of this section shall be at least one hundred nautical miles.

(g) There shall be provided between the bridge of the ship and the radio room, and between the bridge and location of the direction finding apparatus, when the direction finding apparatus is not located on the bridge, an efficient means of communication independent of any other communication system of the ship.

(h) The direction finding apparatus shall be efficient and capable of receiving clearly perceptible radio signals and of taking bearings from which the true bearing and direction may be determined. It shall be capable of receiving signals on the frequencies prescribed for distress, direction finding, and radio beacons by the General Radio Regulations annexed to the International Telecommunication convention in force and in new installations after the effective date of this part, such other frequencies as the Commission may for safety purposes designate.

LIFEBOATS

Every motor lifeboat, required to be equipped with radio transmitting apparatus to which the United States is a party, by statute, or by regulation made in conformity with a treaty, convention, or statute, shall be fitted with an efficient radio installation under such rules and regulations as the Commission may find necessary to promote the safety of life.

TRANSMISSION OF INFORMATION

The master of every ship of the United States equipped with radio transmitting apparatus, on meeting with dangerous ice, a dangerous derelect a tropical storm, or any other direct danger to navigation, shall cause to be transmitted all pertinent information relating thereto, to ships in the vicinity and to the appropriate authorities, in accordance with rules and regulations issued by the Commission, which authorities of the United States shall, when they consider it necessary promptly bring the information received by them to the knowledge of those concerned and foreign authorities interested.

AUTHORITY OF MASTER

The radio installation, the operators, the regulation of their watches, the transmission and receipt of messages, and the radio service of the ship except as may be regulated by law or international agreement, or by rules and regulations made in pursuance thereof, shall in the case of a ship of the United States be under the supreme control of the master.

FORFEITURES

The following forfeitures shall apply to this part, in addition to the penalties and forfeitures provided by title V of this Act:

(a) Any ship that leaves or attempts to leave any harbor or port of the United States in violation of the provisions of this part, or the rules and regulations of the Commission made in persuance thereof, or any ship of the United States that is navigated outside of any harbor or port in violation of any of the provisions of this part, or the rules and regulations of the Commission made in pursuance thereof, shall forfeit to the United States the sum of 500 dollars, recoverable by way of suit or libel. Each such departure or attempted departure, and in the case of a ship of the United States each day during which such navigation occurs shall constitute a separate offense.

(b) Every willful failure on the part of the master of a ship of the United States to enforce or to comply with the provisions of this Act or the rules and regulations of the Commission as to equipment, operators, watches, or radio service shall cause him to forfeit to the United States the sum of 100 dollars.

CHAPTER X

RULES GOVERNING STANDARD AND HIGH-FREQUENCY BROADCAST STATIONS

Subpart A -- Rules Governing Standard Broadcast Stations

DEFINITIONS

STANDARD BROADCAST STATIONS. -- The term "standard broadcast station" means a station licensed for the transmission of radio-telephone emissions primarily intended to be received by the general public and operated on a channel in the band 550-1600 kilocycles, inclusive.

STANDARD BROADCAST BAND. -- The term "standard broadcast band" means the band of frequencies extending from 550-1600 kilocycles, inclusive, both 550 kilocycles and 1600 kilocycles being the carrier frequencies of broadcast channels.

STANDARD BROADCAST CHANNEL; -- The term "standard broadcast channel" means the band of frequencies occupied by the carrier and two side bands of a broadcast signal with the carrier frequency at the center. Channels shall be designated by their assigned carrier frequencies. Carrier frequencies assigned to standard broadcast stations shall begin at 550 kilocycles and be in successive steps of 10 kilocycles.

DOMINANT STATION. -- The term "dominant station" means a class I station, as hereinafter defined, operating on a clear channel.

SECONDARY STATION. -- The term "secondary station" means any station except a class I station operating on a clear channel.

DAYTIME. -- The term "daytime" means that period of time between local sunrise and local sunset.

NIGHTTIME. -- The term "nighttime" means that period of time between local sunset and 12 midnight local standard time.

SUNRISE and SUNSET. -- The terms "sunrise" and "sunset" mean, for each particular location and during any particular month, the average time of sunrise and sunset as specified in the license of a broadcast station. (For tabulation of average sunrise and sunset times for each month at various points in the United States, see "Average Sunrise and Sunset Times.")

BROADCAST DAY -- The term "broadcast day" means that period of time between local sunrise and 12 midnight local standard time.

EXPERIMENTAL PERIOD . -- The term "experimental period" means that time between 12 midnight and local sunrise. This period may be used for experimental purposes in testing and maintaining apparatus by the licensee of any standard broadcast station on its assigned frequency and with its authorized power, provided no interference is caused to other stations maintaining a regular operating schedule within such period. No station licensed for "daytime" or "specified hours" of operation may broadcast any regular or scheduled program during this period.

SERVICE AREAS. -- (a) The term "primary service area" of a broadcast station means the area in which the ground wave is not subject ot objectionable interference or objectionable fading.

(b) The term "secondary service area" of a broadcast station means the area served by the sky wave and not subject to objectionable interference. The signal is subject to intermittent variations in intensity.

(c) The term " intermittent service area" of a broadcast station means the area receiving service from the ground wave but beyond the primary service area and subject to some interference and fading.

MAIN STUDIO. -- The term "main studio" means, as to any station, the studio from which the majority of its local programs originate, and/or from which a majority of its station announcements are made of programs originating at remote points.

PORTABLE TRANSMITTER. -- The term "portable transmitter" means a transmitter so constructed that it may be moved about conveniently from place to place, and is in fact so moved about from time to time, but not ordinarily used while in motion. In the standard broadcast band, such a transmitter is used in making field intensity measurements for locating a transmitter site for a standard broadcast station. A portable broadcast station will not be licensed in the standard broadcast band for regular transmission of programs intended to be received by the public.

AUXILIARY TRANSMITTER.-- The term "auxiliary transmitter" means a transmitter maintained only for transmitting the regular programs of a station in case of failure of the main transmitter.

COMBINED AUDIO HARMONICS. -- The term "combined audio harmonics" means the arithmetical sum of the amplitudes of all the separate harmonic components. Root sum square harmonic readings may be accepted under conditions prescribed by the commission.

EFFECTIVE FIELD. -- The "effective field" or "effective field intensity" is the root-mean-square (RMS) value of the inverse distance fields at a distance of 1 mile from the antenna in all directions in the horizontal plane.

ALLOCATION OF FACILITIES

THREE CLASSES OF STANDARD BROADCAST CHANNELS. -- (a) CLEAR CHANNEL. A "clear channel" is one on which the dominant station or stations render service over wide areas and which are cleared of objectionable interference within their primary service areas and over all or a substantial portion of their secondary service areas.

(b) REGIONAL CHANNEL. -- A "regional channel" is one on which several stations may operate with powers not in excess of 5 kilowatts. The primary service area of a station operating on any such channel may be limited, as consequence of interference, to a given field intensity contour.

(c) LOCAL CHANNEL. -- A "local channel" is one on which several stations may operate with powers not in excess of 250 watts. The primary service area of a station operating on any such channel may be limited, as a consequence of interference, to a given field intensity contour.

CLASSES AND POWER OF STANDARD BROADCAST STATIONS. -- (a) CLASS I STATION. -- A "class I station" is a dominant station operating on a clear channel and designed to render primary and secondary service over an extended area and at relatively long distances. Its primary service area is free from objectionable interference from other stations on the same and adjacent channels, and its secondary service area free from interference, except from stations on the adjacent channel, and from stations on the same channel in accordance with the channel designation in section 3.25 or in accordance with the "Engineering Standards of Allocation". The operating power shall be not less than 10 kilowatts nor more than 50 kilowatts.

(b) CLASS II STATION. -- A "class II station" is a secondary station which operates on a clear channel (see section 3.25) and is designed to render service over a primary service area which is limited by and subject to such interference as may be received from class I stations. A station of this class shall operate with power not less than 0.25 kilowatts nor more than 50 kilowatts. Whenever necessary a class II station shall use a directional antenna or other means to avoid interference with class I stations and with other class II stations, in accordance with the Engineering Standards of Allocation.

(c) CLASS III STATION. -- A "class III station" is a station which operates on a regional channel and is designed to render service primarily to a metropolitan district and the rural area contiguous thereto.

Class III stations are subdivided into two classes:

(1) Class III -A station. - A "class III -A station" is a class III station which operates with power not less than 1 kilowatt nor more than 5 kilowatts, and the service area of which is subject to interference in accordance with the Engineering Standards of Allocation.

(2) Class III B STATION. - A "class III B station" is a class III station which operates with a power not less than 0.5 kilowatt nor more than 1 kilowatt night and 5 kilowatts daytime, and the service area of which is subject ot interference in accordance with Engineering Standards of Allocation.

(d) CLASS IV STATION. - A "class IV station" is a station operating on a local channel and designed to render service primarily to a city or town and the suburban and rural areas contiguous thereto. The power of a station of this class shall not be less than 0.1 kilowatt nor more than 0.25 kilowatt, and its service area is subject to interference in accordance with the Engineering Standards of Allocation.

TIME OF OPERATION OF THE SEVERAL CLASSES OF STATIONS; -- The several classes of standard broadcast stations may be licensed to operate in accordance with the following: (a) "Unlimited time" permits operation without a maximum limit as to time. (b) "Limited time" is applicable to class II (secondary stations) operating on a clear channel only. It permits operation of the secondary station during daytime, and until local sunset if located west of the dominant station on the channel or is located east thereof, until sunset at the dominant station, and in addition during night hours, if any, not used by the dominant station or stations on the channel. (c) "Daytime" permits operation during the hours between average monthly local sunrise and average monthly local sunset. (For exact time of sunset at any location, see "Average Sunrise and Sunset Times" (d) '"Sharing time" permits operation during hours which are so restricted by the station license as to require a division of time with one or more other stations using the same channel. (e) "Specified hours" means that the exact operating hours are specified in the license. (The minimum hours that any station shall operate are specified in section 3.71)

BROADCAST FACILITIES; SHOWING REQUIRED. -- An authorization for a new standard broadcast station or increase in facilities of an existing station will be issued only after a satisfactory showing has been made in regard to the following, among others:

(a) That the proposed assignment will tend to effect a fair, efficient, and equitable distribution of radio service among the several states and communities .

(b) That objectionable interference will not be caused to existing stations or that if interference will be caused the need for the proposed service outweighs the need for the service which will be lost by reason of such interference. That the proposed station will not suffer interference to such an extent that its service would be reduced to an unsatisfactory degree. (For determining objectionable interference, see Engineering Standards of Allocation and Field Intensity Measurments in Allocation.)

(c) That the applicant is financially qualified to construct and operate the proposed station.

(d) That the applicant is legally qualified. That the applicant (or the person or persons in control of an applicant corporation or other organization) is of good character and posseses other qualifications sufficient to provide a satisfactory public service.

(e) That the technical equipment proposed, the location of the transmitter, and other technical phases of operation comply with the regulations governing the same, and the requirements of good engineering practice. (See technical regulations herein and Locations of Transmitters of Standard Broadcast Stations.)

(f) That the facilities sought are subject to assignment as requested under existing international agreements and the Rules and Regulations of the Commission.

(g) That the public interest, convenience, and necessity will be served through the operation under the proposed assignment.

FREQUENCY ALLOCATIONS BY CLASSES OF STATIONS

CLEAR CHANNELS; CLASSES I AND II - The frequencies in the following tabulation are designated as clear channels and assigned for use by the classes of stations as given:

(a) To each of the channels below there will be assigned one class I station and there may be assigned one or more class II stations operating limited time or daytime only: 640, 650, 660, 670, 700, 720, 740, 750, 760, 770, 800, 810, 820, 830, 850, 860, 870, 980, 990, 1000, 1070, 1090, 1130, 1150, 1170, and 1190 kilocycles. The power of the Class I stations on these channels shall not be less than 50 kilowatts.

(b) To each of the channels below there may be assigned class I and class II stations: 680, 710, 790, 970, 1020, 1040, 1050, 1060 1080, 1100, 1110, 1140, 1160, 1180, 1460, 1470, 1480, and 1490 kilocycles.

REGIONAL CHANNELS; CLASSES III.-A and III - B - The following frequencies are designated as regional channels and are assigned for use by Class III-A and Class III B stations: 550, 560, 570, 580, 590, 600, 610, 620, 630, 780, 880, 890, 900, 920, 930, 940, 950, 1010, 1120, 1220, 1230, 1240, 1250, 1260, 1270, 1280, 1290, 1300, 1320, 1330, 1340, 1350, 1360, 1380, 1390, 1400, 1410, 1430, 1440, 1450, 1530, and 1550 kilocycles.

LOCAL CHANNELS; CLASS IV - The following frequencies are designated as local channels and are assigned for use by class IV stations: 1200, 1210, 1310, 1370, 1420, and 1500 kilocycles.

ASSIGNMENT OF STATIONS TO CHANNELS; - The individual assignments of stations to channels shall be made in accordance with the standards of good engineering practice prescribed and published from time to time by the Commission for the respective classes of stations involved. (For determining objectionable interference, see Engineering Standards of Allocation and Field Intensity Measurements in Allocation, sectionC.)

ASSIGNMENT OF CLASS IV STATIONS TO REGIONAL CHANNELS. - On condition that interference will not be caused to any class III station, and that the channel is used adequately and properly for class III stations and subject to such interference as may be received from class III stations, class IV stations may be assigned to regional channels.

STATION LOCATION - (a) Each standard broadcast station shall be considered located in the State and city where the main studio is located.

(b) The transmitter of each standard broadcast station shall be so located that primary service is delivered to the city in which the main studio is located, in accordance with the Standards of Good Engineering Practice, prescribed by the Commission.

AUTHORITY TO MOVE MAIN STUDIO - The licensee of a standard broadcast station shall not move its main studio outside the borders of the city, State, district, Territory, or possession in which it is located without first making written application to the Commission for authority to so move, and securing written permission for such removal. A licensee need not obtain permission to move the main studio from one location to another within a city or town, but shall promptly notify the Commission of any such change in location.

SPECIAL EXPERIMENTAL AUTHORIZATIONS - (a) Special experimental authorizations may be issued to the licensee of a standard broadcast station in addition to the regular license upon proper application therefor and satisfactory showing in regard to the following, among others:

(1) That the applicant has a program of research and experimentation which indicates reasonable promise of contribution to the development and practical application of broadcasting, and will be in addition to and advancement of the work that can be accomplished under its regular license.

(2) That the experimental operation and experimentation will be under the direct supervision of a qualified engineer with an adequate staff of engineers qualified to carry on the program of research and experimentation.

(3) That the public interest, convenience, and necessity will be served by granting the authorization requested.

(b) In case a special experimental authorization permits additional hours of operation, no licensee shall transmit any commercial or sponsored program or make any commercial announcement during such time of operation. In case of other additional facilities, no additional charge shall be made by reason of transmission with such facilities.

(c) A special experimental authorization will not be extended after the actual experimentation is concluded.

(d) The program of research and experimentation as outlined in the application for a special experimental authorization shall be adhered to in the main unless the licensee is authorized to do otherwise by the Commission.

(e) The Commission may require from time to time a broadcast station holding such experimental authorization to conduct experiments that are deemed desirable and reasonable.

(f) A supplemental report shall be filed with and made a part of each application for an extension of a special experimental authorization and shall include statements of the following:

(1) Comprehensive summary of all research and experimentation conducted.

(2) Conclusions and outline of proposed program for further research and development.

(3) Comprehensive summary and conclusions as to the social and economic effects of its use.

DIRECTIONAL ANTENNA; SHOWING REQUIRED. - (a) No application for authority to install a directional antenna will be accepted unless a definite site and full details of the design of the directional antenna are given with the application. (See Data Required with Applications Involving Directional Antenna Systems.)

(b) No application for an authorization to operate a directional antenna during the broadcast day will be accepted unless proof of performance of the directional antenna taken during equipment test period is submitted with the application. (See Field Intensity Measurements in Allocation, Sec B.)

NORMAL LICENSE PERIOD. - All standard broadcast station licenses will be issued so as to expire at the hour of 3 a.m., Eastern Standard Time, and will be issued for a normal license period of 1 year, expiring as follows:

(a) For stations operating on the frequencies 640, 650, 660, 670, 680, 700, 710, 720, 740, 750, 760, 770, 790, 800, 810, 820, 830, 850, 860, 870, 970, 980, 990, 1000, 1020, 1040, 1050, 1060, 1070, 1080, 1090, 1100, 1110, 1130, 1140, 1150, 1160, 1170, 1180, 1190, 1460, 1480, 1490 kilocycles, February 1.

(b) For stations operating on the frequencies 550, 560, 570, 580, 590, 600, 610, 620, 630, 780, 880, 890, 900, and 920 kilocycles, April 1.

(c) For stations operating on the frequencies 930, 940, 950, 1010, 1120, 1220, 1230, 1240, 1250, 1260, 1270, 1280, and 1290, kilocycles June 1.

(d) For stations operating on the frequencies 1300, 1320, 1340, 1350, 1360, 1380, 1390, 1400, 1410 1420, 1440, 1450, 1530, and 1550 kilocycles, August 1.

(e) For stations operating on the frequencies 1200, 1210, and 1310, kilocycles. October 1.

(f) For stations operating on the frequencies 1370, 1420, and 1500 kilocycles, December 1.

EQUIPMENT

MAXIMUM RATED CARRIER POWER; TOLERANCES. The maximum rated carrier power of a standard broadcast transmitter shall not be less than the authorized power nor shall it be greater than the value specified in the following table:

Class of Station	Maximum power authorized to station.	Maximum rated carrier power permitted to be installed.
Class IV	100 or 250 watts	250 watts
Class III	500 or 1,000 watts	1,000 watts
	5,000 watts	5,000 watts
Class II	250, 500, or 1,000 watts	1,000 watts
	5,000 or 10,000 watts	10,000 watts
	25,000 or 50,000 watts	50,000 watts
Class I	10,000 watts	10,000 watts
	25,000 or 50,000 watts	50,000 watts

MAXIMUM RATED CARRIER POWER; HOW DETERMINED. - The maximum rated carrier power of a standard broadcast transmitter shall be determined as the sum of the applicable power ratings of the vacuum tubes employed in the last radio stage.

(a) The power rating of vacuum tubes shall apply to transmitters employing the different classes of operation or systems of modulation as specified in Power Rating of Vacuum Tubes prescribed by the Commission.

(b) If the maximum rated carrier power of any broadcast transmitter, as determined by paragraph (a) of this section, does not give an exact rating as recognized in the Commission's plan of allocation, the nearest rating thereto shall apply to such transmitter.

(c) Authority will not be granted to employ, in the last radio stage of a standard broadcast transmitter, vacuum tubes from a manufacturer or of a type number not listed until the manufacturer's rating for the class of operation or system of modulation is submitted to and approved by the Commission. These data must be supplied by the manufacturer in accordance with Requirements for the Approval of the Power Rating of Vacuum Tubes, prescribed by the Commission.

CHANGES IN EQUIPMENT; AUTHORITY FOR. -- No licensee shall change, in the last radio stage, the number of vacuum tubes to vacuum tubes of different power rating or class of operation, nor shall it change system of modulation without the authority of the Commission.

OTHER CHANGES IN EQUIPMENT. -- Other changes except as provided for in these rules or Standards of Good Engineering Practice, prescribed by the Commission, which do not affect the maximum power rating or operating power of the transmitter or the operation or precision of the frequency control equipment may be made at any time without authority of the Commission, but in the next succeeding application for renewal of license such changes which affect the information on file shall be shown in full.

RADIATING SYSTEM. -- (a) All applicants for new, additional, or different broadcast facilities and all licensees requesting authority to move the transmitter of an existing station shall specify a radiating system the efficiency of which complies with the requirements of Good Engineering Practice for the class and power of the station. (Also see Use of Common Antenna by Standard Broadcast Stations or Another Radio Station.)

(b) The Commission will publish from time to time specifications deemed necessary to meet the requirements of good engineering practice. (See Minimum Antenna Heights or Field Intensity Requirements and Field Intensity Measurements in Allocation, sec. A.)

(c) No broadcast station licensee shall change the physical height of the transmitting antenna, or supporting structures, or make any changes in the radiating system which will measurably alter the radiation patterns, except upon written application to and authority from the Commission.

(d) The antenna and/or supporting structure shall be painted and illuminated in accordance with the specifications supplied by the Commission pursuant to section 303 (q) of the Communications Act of 1934, as amended. (See Standard Lamps and Paints.)

(e)The simultaneous use of a common antenna or antenna structure by two standard broadcast stations or by a standard broadcast station and a station of any other class or service will not be authorized unless both stations are licensed to the same licensee. (See use of Common Antenna by Standard Broadcast Stations or Another Radio Station.)

TRANSMITTER. -- (a) The transmitter proper and associated transmitting equipment of each broadcast station shall be designed, constructed, and operated in accordance with the Standards of Good Engineering Practice in all phases not otherwise specifically included in these regulations.

(b) The transmitter shall be wired and shielded in accordance with good engineering practice and shall be provided with safety features in accordance with the specifications of Article 810 of the current National Electrical Code as approved by the American Standards Association.

(c) The station equipment shall be so operated, tuned, and adjusted that emissions are not radiated outside the authorized band which cause of which, in accordance with the Standards of Good Engineering Practice, are considered as being capable of causing interference to the communications of other stations. The spurious emmissions, including radio frequency harmonics and audio frequency harmonics, shall be maintained as low a level as required by Good Engineering Practice. The audio distortion, audio frequency range, carrier hum, noise level, and other essential phases of the operation which control the external effects shall at all times conform to the requirements of good engineering practice.

(d) Whenever, in this section, the term "Good Engineering Practice" is used, the specifications deemed necessary to meet the requirements thereof will be published from time to time. (See construction, General Operation and Safety of Life Requirements.)

TECHNICAL OPERATION

OPERATING POWER; HOW DETERMINED. -- The operating power of each standard broadcast station shall be determined by: (a) Direct measurement of the antenna power in accordance with section 3.54.

(1) Each new standard broadcast station.

(2) Each existing standard broadcast station after December 1, 1940.

(b) Indirect measurement by means of the plate input power to the last radio stage on a temporary basis in accordance with sections 3.52 and 3.53.

(1) In the case of existing standard broadcast stations and pending compliance with paragraph (a)(2) of this section.

(2) In case of an emergency where the licensed antenna has been damaged or destroyed by storm or other cause beyond the control of the licensee or pending completion of authorized changes in the antenna system.

(c) Upon making any change in the antenna system, or in the antenna current measuring instruments, or any other change which may change the characteristics of the resistance (see section 3.54) and shall submit application for authority to determine power by the direct method on the basis of the new measurements.

OPERATING POWER; INDIRECT MEASUREMENT. -- The operating power determined by indirect measurement from the plate input power of the last radio stage is the product of the plate voltage (E_p), the total plate current of the last radio stage (I_p) and the proper factor (F) given in the following tables: that is

$$\text{Operating Power} = E_p \times I_p \times F$$

A. Factor to be used for stations employing plate modulation in the last radio stage.*

Maximum rated power of transmitter:†	Factor (F) to be used in determining the operating power from the plate input power.
100 - 1,000 watts	0.70
5,000 watts and over	.80

B. Factor to be used for stations of all powers using low-level modulation[1]

Class of power amplifier in the last radio stage:	Factor (F) to be used in determining the operating power from the plate input power

Class B.	0.35
Class BC[3].	.65

C. Factors to be used for stations of all powers employing grid modulation in the last radio stage[1]

Type of tube in the last radio stage:	Factor (F) to be used in determining the operating power from the plate input power.
Table C[1].	0.25
Table D[1].	.35

1 See Power Rating of Vacuum tubes.
2 The maximum rated carrier power must be distinguished from the operating power.
3 All linear amplifier operation where efficiency approaches that of class C operation.

APPLICATION OF EFFICIENCY FACTORS. - In computing operating power by indirect measurement the above factors shall apply in all cases, and no distinction will be recognized due to the operating power being less than the maximum rated carrier power. (See Plate Efficiency of Last Radio Stage)

OPERATING POWER; DIRECT MEASUREMENT. - The antenna input power determined by direct measurement is the square of the antenna current times the antenna resistance at the point where the current is measured and at the operating frequency. Direct measurement of the antenna input power will be accepted as the operating power of the station, provided the data on the antenna resistance measurements are submitted under oath giving detailed description of the method used and the data taken. The antenna current shall be measured by an ammeter of accepted acuracy. These data must be submitted to and approved by the Commission before any licensee will be authorized to operate by this method of power determination. The antenna ammeter shall not be changed to one of different type, maximum reading or accuracy without the authority of the Commission. If any change is made in the antenna system or any change made which may affect the antenna system, the method of determining operating power shall be changed immediately to the indirect method . (See Further Requirements for Direct Measurements of Power.)

MODULATION. - A licensee of a broadcast station will not be authorized to operate a transmitter unless it is capable of delivering satisfactorily the authorized power with a modulation of at least 85 percent. When the transmitter is operated with 85 percent modulation, not over 10 percent combined audio frequency harmonics shall be generated by the transmitter.

(b) All broadcast stations shall have in operation a modulation monitor approved by the Commission.

(c) The operating percentage of modulation of all stations shall be maintained as high as possible consistent with good quality of transmission and good broadcast practice and in no case less than 85 percent on peaks of frequent recurrence during any selection which normally is transmitted at the highest level of the program under consideration.

(d) The Commission will, from time to time, publish the specifications, requirements for approval, and a list of approved modulation monitors. (See Approved Modulation Monitors and also Requirements for Approval of Modulation Monitors)

MODULATION; DATA REQUIRED. - A licensee of a broadcast station claiming a greater percentage of modulation than the fundamental design indicates can be procured shall submit full data showing the antenna input power by direct measurement and complete information, either oscillograms or other acceptable data, to show that a modulation of 85 percent or more, with not over 10 percent combined audio harmonics, can be obtained with the transmitter operated at the maximum authorized power.

OPERATING POWER; MAINTENANCE OF. - The licensee of a broadcast station shall maintain the operating power of the station within the prescribed limits of the licensed power at all times except that in an emergency when, due to causes beyond the control of the licensee, it becomes impossible to operate with the full licensed power, the station may be operated at reduced power for a period of not to exceed 10 days, provided that the Commission and the Inspector in Charge shall be notified in writing immediately after the emergency develops. (See Operating Power Tolerence.)

INDICATING INSTRUMENTS. - Each broadcast station shall be equipped with suitable indicating instruments of accepted accuracy to measure the antenna current, direct plate circuit voltage, and the direct plate circuit current of the last radio stage. These indicating instruments shall not be changed or replaced, without authority of the Commission, except by instruments of the same type, maximum scale reading, and accuracy. (See Indicating Instruments Pursuant to section 3.58.)

FREQUENCY TOLERANCE. - The operating frequency of each broadcast station shall be maintained within 50 cycles of the assigned frequency until January 1, 1940, and thereafter the frequency of each new station where a new transmitter is installed shall be maintiined within 20 cycles of the assigned frequency, and after January 1, 1942, the frequency of all stations shall be maintained within 20 cycles of the assigned frequency.

FREQUENCY MONITOR. - The licensee of each standard broadcast station shall have in operation at the transmitter a frequency monitor independent of the frequency control of the transmitter. The frequency monitor shall be approved by the Commission. It shall have a stability and accuracy of at least 5 parts per million. (See approved Frequecny Monitors and also Requirements for Approval of Frequency Monitors.)

NEW EQUIPMENT; RESTRICTIONS. - The Commission will authorize the installation of new transmitting equipment in a broadcast station or changes in the frequency control of an existing transmitter only if such equipment is so designed that there is reasonable assurance that the transmitter is capable of maintaining automatically the assigned frequency within the limits specified in section 3.59.

AUTOMATIC FREQUENCY CONTROL EQUIPMENT; AUTHORIZATION REQUIRED. New automatic frequency control equipment and changes in existing automatic frequency control equipment that may affect the precision of frequency control or the operation of the transmitter shall be installed only upon authorization from the Commission. (See Approved Equipment)

AUXILIARY TRANSMITTER. - Upon showing that a need exists for the use of an auxiliary transmitter in addition to the regular transmitter of a broadcast station a license therefor may be issued provided that:

(a) An auxiliary transmitter may be installed either at the same location as the main transmitter or at another location.

(b) A licensed operator shall be in control whenever an auxiliary transmitter is placed in operation.

(c) The auxiliary transmitter shall be maintained so that it may be put into immediate operation at any time for the following purposes:

(1) The transmission of the regular programs upon the failure of the main transmitter.
(2) The transmission of regular programs during maintenance or modification work on the main transmitter, necessitating discontinuance of its operation for a period not to exceed five days.
(3) Upon request by a duly authorized representative of the Commission.

(d) The auxiliary transmitter shall be tested at least once each week to determine that it is in proper operating condition and that it is adjusted to the proper frequency, except that in case of operation in accordance with paragraph (c) of this section during any week, the test in that week may be omitted provided the operation under paragraph (c) is satisfactory. A record shall be kept of the time and result of each test operating under paragraph (c). Tests shall be conducted only between midnight and 9 a.m. local standard time.

(e) The auxiliary transmitter shall be equipped with satisfactory control equipment which will enable the maintenance of the frequency emitted by the station within the limits prescribed by these regulations.

(f) An auxiliary transmitter which is licensed at a geographical location different from that of the main transmitter shall be equipped with a frequency control which will automatically hold the frequency within the limits prescribed by these regulations without any manual adjustment during operation or when it is being put into operation.

(g) The operating power of an auxiliary transmitter may be less than the authorized power, but in no event shall it be greater than such power.

DUPLICATE MAIN TRANSMITTERS. -- The licensee of a standard broadcast station may be licensed for duplicate main transmitter provided that a technical need for such duplicate transmitters is shown and that the following conditions are met:

(a) Both transmitters are located at the same place.
(b) The transmitters have the same power rating.
(c) The external effects from both transmitters is substantially the same as to frequency stability, reliability of operation, radio harmonics and other spurious emmissions, audio frequency range and audio harmonic generation in the transmitter.

OPERATION

MINIMUM OPERATING SCHEDULE. -- Except Sundays, the licensee of each standard broadcast station shall maintain a minimum operating schedule of two-thirds of the total hours that it is authorized to operate between 6 p.m. and midnight, local standard time, except that in an emergency, when, due to causes beyond the control of the licensee, it becomes impossible to continue operating, the station may cease operation for a period of not to exceed 10 days provided that the Commission and the Inspector in Charge shall be notified in writing immediately after the emergency develops.

OPERATION DURING EXPERIMENTAL PERIOD. -- The licensee of each standard broadcast station shall operate or refrain from operating its station during the experimental period as directed by the Commission in order to facilitate frequency measurement or for the determination of interference. (Stations involved in the after-midnight frequency monitoring programs are notified of their operating and silent schedule.)

SPECIFIED HOURS. -- If the licensee of a station specifies the hours of operation, the schedule so specified shall be adhered to except as provided in sections 3.71 and 3.72.

SHARING TIME. -- If the licenses of stations authorized to share time do not specify hours of operation, the licensees shall endeavor to reach an agreement for a definite schedule of periods of time to be used by each. Such agreement shall be in writing and each licensee shall file the same in triplicate original with each application to the Commission for renewal of license. If and when such written agreements are properly filed in conformity with this section the file mark of the Commission will be affixed thereto, one copy will be retained by the Commission, one copy forwarded to the Inspector in Charge, and one copy returned to the licensee to be posted with the station license and considered as a part thereof. If the license specifies a proportionate time division, the agreement shall maintain this proportion. If no proportionate time division is specified in the license, the licensees shall agree upon a division of time. Such division of time shall not include simultaneous operation of the stations unless specifically authorized by the terms of the license.

SHARING TIME; EQUIVALENCE OF DAY AND NIGHT HOURS. -- For the purpose of determining the proportionate division of time of the broadcast day for sharing time stations, 1 night hour shall be considered the equivalent of 2 day hours.

SHARING TIME; EXPERIMENTAL PERIOD. -- If the license of a station authorized to share time does not specify the hours of operation, the station may be operated for the transmission of regular programs during the experimental period provided an agreement thereto is reached with the other stations with which the broadcast day is shared and further provided such operation is not in conflict with section 3.72. Time sharing agreements for operation during the experimental period need not be submitted to the Commission.

SHARING TIME; DEPARTURE FROM REGULAR SCHEDULE. -- A departure from the regular operating schedule set forth in a time sharing agreement will be permitted only in cases where an agreement to that effect is reduced to writing, is signed by the licensees of the stations affected thereby and filed in triplicate by each licensee with the Commission prior to the time of proposed change. If time is of the essence, the actual departure in operating schedule may precede the actual filing of written agreement, provided appropriate notice is sent to the Commission and the Inspector in Charge.

SHARING TIME STATIONS; NOTIFICATION TO COMMISSION. -- If the licensees of stations authorized to share time are unable to agree on a division of time, the Commission shall be so notified by statement to that effect filed with the applications for renewals of licenses. Upon receipt of such statement the Commission will designate the applications for a hearing and, pending such hearing the operating schedule previously adhered to shall remain in full force and effect.

LICENSE TO SPECIFY SUNRISE AND SUNSET HOURS. -- If the licensee of a broadcast station is required to commence or cease operation of the station at the time of sunrise or sunset, the license will specify the hour of the day during each month of the license period when operation of such station will commence or cease. (See Average Sunrise and Sunset Time.)

SECONDARY STATION; FILING OF OPERATING SCHEDULE. -- The licensee of a secondary station authorized to operate limited time and which may resume operation at the time the dominant station (or stations) on the same channel ceases operation shall, with each application for renewal of license, file in triplicate a copy of its regular operating schedule, bearing a signed notation by the licensee of the dominant station of its objection or lack of objection thereto. Upon approval of such operating schedule, the Commission will affix its file mark and return one copy to the licensee authorized to operate limited time, which shall be posted with the station license and considered as a part thereof. Departure from said operating schedule will be permitted only in accordance with the procedure set forth in section 3.77.

SECONDARY STATION; FAILURE TO REACH AGREEMENT. -- If the licensee of a secondary station authorized to operate limited time and a dominant station on a channel are unable to agree upon a definite time for resumption of operation by the station authorized limited time, the Commission shall be so notified by the licensee of the station authorized limited time. After receipt of such statement the Commission will designate for hearing the applications of both stations for renewal of license, and pending the hearing the schedule previously adhered to shall remain in full force and effect.

DEPARTURE FROM SCHEDULE; MATERIAL VIOLATION. -- In all cases where a station licensee is required to prepare and file an operating schedule, any deviation or departure from such schedule, except as herein authorized, shall be considered a violation of a material term of the license.

LOCAL STANDARD TIME. -- All references herein to standard time or local standard time refer to local standard time as determined and fixed by the Interstate Commerce Commission.

DAYLIGHT SAVING TIME. -- If local time is changed from standard time to daylight saving time at the location of all stations sharing time on the same channel the hours of operation of all such stations on that channel shall be understood to refer to daylight saving time, and not standard time, as long as daylight saving time is observed at such locations. This provision shall govern when the time is changed by provision of law or general observance of daylight saving time by the various communities, and when the time of operation of such stations is specified in the license or is mutually agreed upon by the licensees: Provided, However, That when the license specifies average time of sunrise and sunset, local standard time shall be observed. In no event shall a station licensed for daytime only operate on regular schedule prior to local sunrise, or shall a station licensed for greater daytime power than nighttime power or for a different radiation pattern for daytime operation than for nighttime operation operate with the daytime power or radiation pattern prior to local sunrise.

CHANGES IN TIME; AGREEMENT BETWEEN LICENSEES. -- Where the local time is not changed from standard time to daylight saving time at the location of all stations sharing time on the same channel, the hours of operation of such stations shall be understood to have reference to standard time, and not daylight saving time, unless said licensees mutually agree upon a new schedule which shall be effective only while daylight saving time is observed at the location of some of these stations.

LOCAL STANDARD TIME; LICENSE PROVISIONS. -- The time of operation of any broadcast station which does not share time with other stations on the same channel shall be understood to have reference to local standard time unless modification of such license with respect to hours of operation is authorized by the Commission.

SUBPART B-RULES GOVERNING HIGH-FREQUENCY BROADCAST STATIONS

DEFINITIONS

HIGH-FREQUENCY BROADCAST STATION. - The term " high - frequency broadcast station" means station licensed primarily for the transmission of radiotelephone emissions intended to be received by the general public and operated on a channel in the high frequency broadcast band.

HIGH-FREQUENCY BROADCAST BAND. - The term "high - frequency broadcast band" means the band of frequencies extending from 43,000 to 50,000 kilocycles, both inclusive.

FREQUENCY MODULATION.- The term "frequency modulation" means a system of modulation of a radio signal in which the frequency of the carrier wave is varied in accordance with the signal to be transmitted while the amplitude of the carrier remains constant.

CENTER FREQUENCY.- The term "center frequecny" means the frequency of the carrier wave with no modulation (With modulation the instantaneous operating frequency swings above and below the center frequency. The operating frequency with no modulation shall be the center frequency within the frequency tolerance.)

HIGH-FREQUENCY BROADCAST CHANNEL.- The term"high-frequency broadcast channel" means a band of frequencies 200 kilocycles wide and is designated by its center frequency. Channels for high-frequency broadcast stations begin at 43,100 kilocycles and continue in successive steps of 200 kilocycles to and including the frequency 49,000 kilocycles.

SERVICE AREA. - The term "service area" of a high - frequency broadcast station means the area in which the signal is not subject to objectionable interference or objectionable fading. (High-frequency broadcast stations are considered to have only one service area; for determination of such area see Standards of Good Engineering practice for High-Frequency Broadcast Stations.)

ANTENNA FIELD GAIN. - The term "antenna field gain" of a high - frequency broadcast antenna means the ratio of the effective free space field intensity produced at one mile in the horizontal plane expressed in millovolts per meter for 1 kilowatt antenna input power to 137.6.

FREE SPACE FIELD INTENSITY. - The term "free space field intensity " means the field intensity that would exist at a point in the absence of waves reflected from the earth or other reflecting objects.

FREQUENCY SWING.- The term "frequency swing" is used only with respect to frequency modulation and means the instantaneous departure of the carrier frequency from the center frequency resulting from modulation.

MULTIPLEX TRANSMISSION. - The term "multiplex transmission" means the simultaneous transmission of two or more signals by means of a common carrier wave. (Multiplex transmission as applied to high - frequency broadcast stations means the transmission of facsimile or other aural signals in addition to the regular broadcast signals.)

PERCENTAGE MODULATION. - The term "percentage modulation" with respect to frequency modulation means the ratio of the actual frequency swing to the frequency swing required for 100 percent modulation expressed in percentage. (For high - frequency broadcast stations, a frequency swing of 75 kilocycles is standard for 100 percent modulation.)

EXPERIMENTAL PERIOD. - The term "experimental period" means that period of time between 12 midnight and sunrise. This period may be used for experimental purposes in testing and maintaining apparatus by the licensee of any high -frequency broadcast station, on its assigned frequency and with its authorized power, provided no interference is caused to other stations maintaining a regular operating schedule within such period.

MAIN STUDIO. - The term "main studio" means, as to any station, the studio from which the majority of its local programs originate, and/or from which a majority of its station announcements are made of programs originating at remote points.

ALLOCATION OF FACILITIES

BASIS OF LICENSING HIGH-FREQUENCY BROADCAST STATIONS. - High-frequency broadcast stations shall be licensed to serve a specified area in square miles. The contour bounding the service area and the radii of the contour shall be determined in accordance with the Standards of Good Engineering Practice for High-Frequency Broadcast Stations.

SERVICE AREAS; DEFINITIONS. - For the purpose of determining the areas to be served by high-frequency broadcast stations, the following definitions apply:

(a) "Basic trade areas" and "limited trade areas" consist of areas the boundaries of which are determined by the Commission on the basis of showings made in applications as to retail trading areas or consumer trading areas and from Government data. Each basic trade area includes one "principal city". The boundaries of the basic trade areas are adjoining and the aggregate of all such areas is the total area of the United States. Each "limited trade area" includes one city. The boundaries of limited trade areas are not necessarily adjoining. Such areas may include portions of other limited trade areas and may extend into more than one basic trade area.

(b) "Principal city" means the largest city or the city or cities designated as principal city by the Commission, within a basic trade area. "City" means any city, town, or borough in a basic trade area except the principal city. Each "city" has a limited trade area.

(c) "Rural area" means all land area outside incorporated towns or cities with population greater than 2,500 and where the density of population is less than 150 per square mile. Incorporated towns or cities with population from 2,500 to 5,000 without a high-frequency broadcast station and not adjacent to larger cities may be considered rural areas.

SERVICE AREAS; ESTABLISHED. - The commission in considering applications for high- frequency broadcast stations will establish service areas. Such stations will be licensed to serve areas having the following characteristics:

(a) An area comprising a limited trade area and a city. The station shall render good service to the city and its service area shall confrom generally with the limited trade area.

(b) An area comprising a basic trade area and a principal city. The station shall render good service to the principal city and its service area shall conform generally with the basic trade area.

(c) An area of at least 15,000 square miles comprising primarily a large rural area, and particularly that part of basic trade areas which cannot be served by stations assigned basic trade areas due to economic and technical limitations. The service area may include one or more principal city or cities, provided that in rendering service to such cities the service to rural areas which the station is designated to serve is not impaired. The transmitter of such a station shall be located in such a manner that the service area. (1) shall extend into two or more basic trade areas, (2) shall not conform generally with a basic trade area, and (3) shall not merely extend beyond a basic trade area.

(d) An area having substantially different characteristics (social, cultural, or economic) from those areas specified in subsections (a), (b), and (c) of this section where, by reason of special conditions, it is shown that a need (which cannot be supplied by a station serving areas under subsections (a), (b), or (c) of this section) for the proposed service both program and technical exists which makes the establishment of the service area in the public interest, convenience, or necessity. The Commission will give particular consideration in this con nection to competitive advantages which such stations would have over other stations established under other provisions.

(e) In case it is not economically and technically feasible for a station assigned a basic or limited trade area to serve substantially all such area, the Commission will establish the service area on the basis of conditions which prevail in the trade area.

(f) In case an applicant proposes a change in an established service area, the applicant shall make a full showing as to need for such change and the effect on the other stations serving the area.

TIME OF OPERATION. - All high frequency broadcast stations shall be licensed for unlimited time operation.

SHOWING REQUIRED.- Authorization for a new high-frequency broadcast station or increase in facilities of an existing station will be issued only after a satisfactory showing has been made in regard to the following matters:

(a) That the area which the applicant proposes to serve has the characteristics of an area described in section 3.223 hereof.

(b) Where a service area has been established in which one or more existing high-frequency broadcast stations are in operation, that the contours of any new station proposed to serve such area will compare with those of the existing station or stations as nearly as possible, or that the service area already established should be modified.

(c) That objectionable interference will not be caused to existing stations or that if interference will be caused the need for the proposed service outweigh the need for the service which will be lost by reason of such interference.

(d) That the proposed station will not suffer interference to such an extent that its service would be reduced to an unsatisfactory degree. (For determining objectionable interference, see Standards of Good Engineering Practice for High-frequency Broadcast Stations.)

(e) That the technical equipment proposed, the location of the transmitter, and other technical phases of operation comply with the regulations governing the same, and the requirements of good engineering practice. (See technical regulations herein and Standards of Good Engineering Practice for High - Frequency Broadcast Stations.)

(f) That the applicant is financially qualified to construct and operate the proposed station; and, if the proposed station is to serve substantially the same area as an existing station, that applicant will be able to compete effectively with the existing station or stations.

(g) That the program service will include a portion of programs particularly adapted to a service utilizing the full fidelity capability of the system, as set forth in the Standards of Good Engineering Practice for High-Frequency Broadcast Stations.

(h) That the proposed assignment will tend to effect a fair, efficient, and equitable distribution of radio service among the several states and communities.

(i) That the applicant is legally qualified, is of good character, and possesses other qualifications sufficient to provide a satisfactory public service.

(j) That the facilities sought are subject to assignment as requested under existing international agreements and the Rules and Regulations of the Commission.

(k) That the public interest, convenience, and necessity will be served through the operation under the proposed assignment.

CHANNEL ASSIGNMENTS. - The channels set forth below with the indicated center frequencies are available for assignment to high-frequency broadcast stations to serve the areas provided in section 3.223:

(a) An applicant for a station to serve an area specified in section 3.223 (a) or (b) to be located in a principal city or city which has a population less than 25,000 (city only) shall apply for one of the following channels:

48900	49500
49100	49700
49300	49900

(b) An applicant for a station to serve an area specified in section 3.223 (a) or (b); to be located in a principal city or city which has a population greater than 25,000 (city only) shall apply for one of the following channels

44500	45300	46100	46900	47700	48500
44700	45500	46300	47100	47900	48700
44900	45700	46500	47300	48100	
45100	45900	46700	47500	48300	

SPECIAL PROVISIONS CONCERNING ASSIGNMENTS. -- (a) Stations located in the same city shall have substantially the same service area.

(b) High-frequency broadcast stations shall use frequency modulation exclusively.

(c) Stations serving a substantial part of the same area shall not be assigned to adjacent channels.

(d) One channel only will be assigned to a station.

FACSIMILE BROADCASTING AND MULTIPLEX TRANSMISSION. -- The Commission may grant authority to a high-frequency broadcast station for the multiplex transmission of facsimile and aural broadcast programs provided the facsimile transmission is incidental to the aural broadcast programs and does not either reduce the quality of or the frequency swing required for the transmission of the aural program. The frequency swing for the modulation of the aural program should be maintained at 75 kc. and the facsimile signal added thereto. No transmission outside the authorized band of 200 kc. shall result from such multiplex operation nor shall interference be caused to other stations operating on adjacent channels. The transmission of multiplex signals may also be authorized on an experimental basis in accordance with section 3.32, subpart A

PROOF OF PERFORMANCE REQUIRED. -- Within 1 year of the date of first regular operation of a high-frequency broadcast station, continuous field intensity records along several radials shall be submitted to the Commission which will establish the actual field contours, and from which operating constants required to deliver service to the area specified in the license are determined. The Commission may grant extensions of time upon showing of reasonable need therefor.

MULTIPLE OWNERSHIP. -- (a) No person (including all persons under common control) shall, directly or indirectly, own, operate, or control more than one high-frequency broadcast station that would serve substantially the same service area as another high-frequency broadcast station owned, operated, or controlled by such person.

(b) No person (including all persons under common control) shall, directly or indirectly own, operate, or control more than one high-frequency broadcast station, except upon a showing

(1) that such ownership, operation, or control would foster competition among high-frequency broadcast stations or provide a high-frequency broadcasting service distinct and separate from existing services, and

(2) that such ownership, operation, or control would not result in the concentration of control of high-frequency broadcasting facilities in a manner inconsistent with public interest, convenience, or necessity; Provided, That, the Commission will consider the ownership, operation, or control of more than six high-frequency broadcast stations to constitue the concentration of control of high-frequency broadcasting facilities in a manner inconsistent with public interest, convenience, or necessity.

NORMAL LICENSE PERIOD. -- All high-frequency broadcast station licenses will be issued so as to expire at the hour of 3 a.m., eastern standard time, and will be issued for a normal license period of 1 year, expiring as follows:

(a) For stations operating on the frequencies 48900, 49100, 49300, 49500, 49700 and 49900, April 1.

(b) For stations operating on the frequencies 44500, 44700, 44900, 45100, 45300, 45500, 45700, 45900, 46100, 46300, and 46500, May 1.

(c) For stations operating on the frequencies 46700, 46900, 47100, 47300, 47500, 47700, 47900, 48100, 48300, 48500, and 48700, June 1.

(d) For stations operating on the frequencies 43100, 43300, 43500, 43700, 43900, 44100, and 44300, July 1.

EQUIPMENT

MAXIMUM POWER RATING. -- The Commission will not authorize the installation of a transmitter having a maximum rated power more than twice the operating power of the station.

MAXIMUM RATED CARRIER POWER; HOW DETERMINED. -- (a) The maximum rated carrier power of a standard transmitter shall be determined by the manufacturer's rating of the equipment.

(b) The maximum rated carrier power of a composite transmitter shall be determined by the sum of the applicable commercial ratings of the vacuum tubes employed in the last radio stage.

FREQUENCY MONITOR. -- The licensee of each high-frequency broadcast station shall have in operation at the transmitter a frequency monitor independent of the frequency control of the transmitter. It shall have a stability of 20 parts per million. For detailed requirements thereof, see Standards of Good Engineering Practice for High Frequency Broadcast Stations.

MODULATION MONITOR. -- The licensee of each high-frequency broadcast station shall have in operation at the transmitter an approved modulation monitor. For detailed requirements thereof, see Standards of Good Engineering Practice for High-Frequency Broadcast Stations.

REQUIRED TRANSMITTER PERFORMANCE. -- (a) The external performance of high-frequency broadcast transmitters shall be within the minumum requirements prescribed by the Commission contained in the Standards of Good Engineering Practice for High-Frequency Broadcast Stations.

(b) The transmitter center frequency shall be controlled directly by automatic means which do not depend on inductances and capacities for inherent stability.

(c) The transmitter shall be wired and shielded in accordance with good engineering practice and shall be provided with safety features in accordance with the specifications of article 810 of the current National Electric Code as approved by the American Standards Association.

INDICATING INSTRUMENTS. -- The direct-plate-circuit current and voltage shall be measured by instruments having an acceptable accuracy. (See Standards of Good Engineering Practice for High-Frequency Broadcast Stations.)

AUXILIARY AND DUPLICATE TRANSMITTERS. -- See Sections 3.63 and 3.64 for provisions governing the use of auxiliary and duplicate transmitters at high-frequency broadcast stations.

CHANGES IN EQUIPMENT AND ANTENNA SYSTEM. -- Licensees of high-frequency broadcast stations shall observe the following provisions with regard to changes in equipment and antenna system:

(a) No change in equipment shall be made:

(1) That would result in the emission of signals outside of the authorized channel.

(2) That would result in the external performance of the transmitter being in disagreement with that prescribed in the Standards of Good Engineering Practice for High-Frequency Broadcast Stations.

(b) Specific authority, upon filing formal application therefor, is required for a change in service area or for any of the following changes:

(1) Changes involving an increase in the maximum power rating of the transmitter.

(2) A replacement of the transmitter as a whole.

(3) Change in the location of the transmitter antenna.

(4) Change in antenna system, including transmission line, which would result in a measurable change in service or which would affect the determination of the operating power by the direct method. If any change is made in the antenna system or any change is made which may affect the antenna system, the method of determining operating power shall be changed immediately to the indirect method.

(5) Change in location of main studio to outside of the borders of the city, state, district, territory, or possession.

(6) Change in power delivered to the antenna.

(c) Specific authority, upon filing informal request therefor is required for the following change in equipment and antenna:

(1) Change in the indicating instruments installed to measure the antenna current or transmission line, direct plate circuit voltage, and the direct current of the last radio stage, except by instruments of the same type, maximum scale reading and accuracy.

(2) Minor changes in the antenna system and/or transmission line which would not result in an increase of the service area.

(3) Changes in the location of the main studio except as provided for in sub-paragraph (b)(5).

(d) Other changes, except as above provided for in this section or in Standards of Good Engineering Practice for High-Frequency Broadcast Stations prescribed by the Commission may be made at any time without the authority of the Commission, provided that the Commission shall be promptly notified thereof, and such changes shall be shown in the next application for renewal of license.

TECHNICAL OPERATION

OPERATING POWER; HOW DETERMINED. -- The operating power, and the requirements for maintenance thereof,of each high frequency broadcast station shall be determined by the Standards of Good Engineering Practice for High-Frequency Broadcast Stations.

MODULATION. -- The percentage of modulation of all stations shall be maintained as high as possible consistent with good quality of transmission and good broadcast practice and in no case less than 85 percent on peaks of frequent recurrence during any selection which normally is transmitted at the highest level of the program under consideration.

FREQUENCY TOLERANCE; -- The operating frequency without modulation of each broadcast station shall be maintained within 2000 cycles of the assigned center frequency.

OPERATION

MINIMUM OPERATING SCHEDULE; SERVICE. -- (a) Except Sundays, the licensee of each high frequency broadcast station shall maintain a regular daily operating schedule which shall consist of at least 3 hours of operation during the period 6 a.m. to 6 p.m. , local standard time and 3 hours of operation during the period 6. p.m. to midnight, local standard time. In an emergency, however, when due to causes beyond the control of the licensee, it becomes impossible to continue operation, the station may cease operation for a period of not to exceed 10 days, provided that the commission and the inspector in charge of radio district in which the station is located shall be notified in writing immediately after the emergency develops.

(b) Such stations shall devote a minimum of 1 hour each day during the period 6 a.m. to 6 p.m, and 1 hour each day during the period 6 p.m. to midnight to programs not duplicated simultaneously as primary service in the same area by any standard broadcast station or by any high frequency broadcast station. During said 1 hour periods, a service utilizing the full fidelity capacity of the system, as set forth in the Standards of Good Engineering Practice for High Frequency Broadcast Stations, shall be rendered. However, the Commission may, upon request accompanied by a showing of reason therefor, grant exemption from the foregoing requirements, in whole or in part, for periods not in excess of 3 months.

(c) In addition to the foregoing minimum requirements, the Commission will consider, in determining whether public interest, convenience, and necessity has been or will be served by the operation of the station, the extent to which the station has been made or will make use of the facility to develop a distinct and separate service from that otherwise available in the service area.

SUBPART C -- GENERAL RULES APPLICABLE TO BOTH STANDARD AND HIGH-FREQUENCY BROADCAST STATIONS

STATION LICENSE; POSTING OF. -- The station license and any other instrument of authorization of individual order concerning construction of the equipment or the manner of operation of the station shall be posted in a conspicuous place in the room in which the transmitter is located in such manner that all terms thereof are visible and the license of the station operator shall be posted in the same manner. (See secs. 2.51 and 2.52)

LICENSED OPERATOR REQUIRED. -- The licensee of each station shall have a licensed operator or operators of the grade specified by the Commission on duty during all periods of actual operation of the transmitter at the place where the transmitting equipment is located. (See sec. 25.3)

LICENSED OPERATOR; OTHER DUTIES. -- The licensed operator on duty and in charge of a standard broadcast transmitter may, at the discretion of the licensee, be employed for other duties or for the operation of another radio station or stations in accordance with the class of operator's license which he holds and by the rules and regulations governing such other stations: Provided, However, That such duties shall in no wise interfere with the proper operation of the standard broadcast transmitter.

LOGS. -- The licensee of each broadcast station shall maintain program and operating logs and shall require entries to be made as follows:

(a) In the program log:

(1) An entry of the time each station identification announcement (call letters and location) is made.

(2) An entry briefly describing each program broadcast, such as "music", "drama", "speech", etc., together with the name or title thereof, and the sponsor's name, with the time of the beginning and ending of the complete program. If a mechanical record is used, the entry shall show the exact nature thereof, such as "record", "transcription", etc., and the time it is announced as a mechanical record. If a speech is made by a political candidate, the name and political affiliations of such speaker shall be entered.

(3) An entry showing that each sponsored program broadcast has been announced as sponsored, paid for, or furnished by the sponsor.

(b) In the operating log:

(1) An entry of the time the station begins to supply power to the antenna, and the time it stops.

(2) An entry of the time the program begins and ends.

(3) An entry of each interruption to the carrier wave, its cause, and duration.

(4) An entry of the following each 30 minutes:

(i) Operating constants of the last radio stage (total plate current and plate voltage.)

(ii) Antenna current.

(iii) Frequency monitor reading.

(iv) Temperature of crystal control chamber if thermometer is used.

(5) Log of experimental operation during experimental period. (If regular operation is maintained during this period, the above lobs shall be kept.)

(i) A log must be kept of all operation during the experimental period. If the entries required above are not applicable thereto, then the entries shall be made so as to fully describe the operation.

LOGS; RETENTION OF. -- Logs of standard broadcast stations shall be retained by the licensee for a period of 2 years, except when required to be retained for a longer period in accordance with the provisions of section 2.54.

STATION IDENTIFICATION. -- (a) A licensee of a standard broadcast station shall make station identification announcement (call letters and location) at the beginning and ending of each time of operation and during operation on the hour and half hour as provided below:

(b) Such identification announcement during operation need not be made when to make such announcement would interrupt a single consecutive speech, play, religious service, symphony concert, or operatic production of longer duration than 30 minutes. In such cases the identification announcement shall be made at the first interruption of the entertainment continuity and at the conclusion of such program.

(c) In case of variety-show programs, baseball game broadcasts, or similar programs of longer duration than 30 minutes, the identification announcement shall be made within 5 minutes of the hour and half hour.

(d) In case of all other programs (except as provided in paragraphs (b) and (c) of this section) the identification announcement shall be made within 2 minutes of the hour and half hour.

(e) In making the identification announcement the call letters shall be given only on the channel of the station identified thereby.

MECHANICAL RECORDS. -- Each broadcast program consisting of a series of mechanical records shall be announced in the manner and to the extent set out below:

(a) A mechanical record or a series thereof, of longer duration than 30 minutes, shall be identified by appropriate announcement at the beginning of the program, at each 30 minutes interval, and at the conclusion of the program: Provided, However, That the identifying announcement at each 30 minutes interval is not required in case of a mechanical record consisting of a single continuous, uninterrupted speech, play, religious service, symphony concert, or operatic production of longer duration than 30 minutes.

(b) A mechanical record, or a series thereof, of a longer duration than 5 minutes, and not in excess of 30 minutes, shall be identified by an appropriate announcement at the beginning and end of the program.

(c) A single mechanical record of a duration not in excess of 5 minutes shall be identified by appropriate announcement immediately preceding the use thereof.

(d) In case a mechanical record is used for background music, sound effects, station identification of the sponsorship of the program proper, no announcement of the mechanical record is required.

(e) The identifying announcement shall accurately describe the type of mechanical record used, i.e., where an electrical transcription is used it shall be announced as a "transcription", or an "electrical transcription", or "electrically transcribed", and where a phonograph record is used it shall be announced as a "record".

REBROADCAST. -- (a) The term "rebroadcast" means reception by radio of the program of a radio station, and the simultaneous or subsequent retransmission of such program by a broadcast station.

(b) The licensee of a standard or high-frequency broadcast station may, without further authority of the Commission, rebroadcast the program of a United States standard or high-frequency broadcast station, provided the Commission is notified of the call letters of each station rebroadcast and the licensee certifies that express authority has been received from the licensee of the station originating the program.

(c) The licensee of a standard or high-frequency broadcast station may, without further authority of the Commission, rebroadcast on a non-commercial basis a non-commercial program of an international broadcast station, provided the Commission is notified of the call letters of each station rebroadcast and the licensee certifies that express authority has been received from the licensee of the station originating the program.

(d) No licensee of a standard broadcast station shall rebroadcast the program of any other class of United States radio station without written authority having first been obtained from the Commission upon application accompanied by written consent or certification of consent of the licensee originating the program.

(e) In case of a program rebroadcast by several standard broadcast stations, such as a chain rebroadcast, the person legally responsible for distributing the program or network facilities may obtain the necessary authorization for the entire rebroadcast both from the Commission and from the person or licensee of the station originating the program.

Attention is directed to section 325 (b) of the Communications Act of 1934, which reads as follows:

No person shall be permitted to locate, use, or maintain a radio broadcast studio or other place or apparatus from which or whereby sound waves are converted into electrical energy, or mechanical or physical reproduction of sound waves produced, and caused to be transmitted or delivered to a radio station in a foreign country for the purpose of being broadcast from any radio station there, having a power output of sufficient intensity, and/or being so located geographically that its emissions may be received consistently in the United States, without first obtaining a permit from the Commission upon proper application therefor.

BROADCASTS BY CANDIDATES FOR PUBLIC OFFICE

GENERAL REQUIREMENTS. - No station licensee is required to permit the use of its facilities by any legally qualified candidate for public office, but if any licensee shall permit any such candidate to use its facilities, it shall afford equal opportunities to all other such candidates for that office to use such facilities, provided that such licensee shall have no power of censorship over the material broadcast by any such candidate.

DEFINITIONS. - The following definitions shall apply for the purposes of Section 3.421:

(A) "A legally qualified candidate" means any person who has met all the requirements prescribed by local, state, or federal authority as a candidate for the office which he seeks, whether it be municipal, county, state, or national, to be determined according to the applicable local laws.

(B) "Other candidates for that office" means all other legally qualified candidates for the same public office.

RATES AND PRACTICES. - The rates, if any, charged all such candidates for the same office shall be uniform and shall not be rebated by any means, directly or indirectly; no licensee shall make any discrimination in charges, practices, regulations, facilities, or services for or in connection with the service rendered pursuant to these rules, or make or give any preference to any candidate for public office or subject any such candidate to any prejudice or disadvantage; nor shall any licensee make any contract or other agreement which shall have the effect of permitting any legally qualified candidate for any public office to broadcast to the exclusion of other legally qualified candidates for the same public office.

RECORDS; INSPECTION. - Every licensee shall keep and permit public inspection of a complete record of all requests for broadcast time made by or on behalf of candidates for public office, together with an appropriate notation showing the disposition made by the licensee of such requests, and the charges made, if any, if request is granted.

CHAPTER XI

RULES GOVERNING EMERGENCY RADIO SERVICE

DEFINITIONS

EMERGENCY SERVICE. - The term "emergency service" means a radiocommunication service carried on for emergency purposes.

MUNICIPAL POLICE STATION. - The term "municipal police station" means a station used by a municipal or county police department for emergency radiotelephone service with mobile police units.

STATE POLICE STATION. - The term "State police station" means a station used by a State police department for emergency radiotelephone service with mobile police units.

INTERZONE POLICE STATION. - The term "interzone police station" means a station used by a police department for radiotelegraph communication (a) with similarly licensed stations in adjacent zones or with the nearest interzone police station, in case there is no similarly licensed station in the adjacent zone, (b) with stations within the zone, and (c) with mobile police units equipped for radiotelegraph reception.

ZONE POLICE STATION. - The term "zone police station" means a station used by police departments for radiotelegraph communication (a) with stations within the zone, (b) with mobile police units equipped for radiotelegraph reception, and (c) with stations in adjacent zone, provided, in each case, express permission of the interzone stations in control of communications is obtained in accordance with the operating procedure prescribed bythe Commission.

MARINE FIRE STATION. - The term "marine fire station" means a station used for intercommunication between municipal fire departments and fireboats.

SPECIAL EMERGENCY STATION. - The term "special emergency station" means a station used for communications in emergencies in lieu of normal means of communication.

FORESTRY STATION. - The term "forestry station" means a station used for communication necessary for the prevention and suppression of forest fires.

GENERAL RULES GOVERNING EMERGENCY RADIO SERVICES

ELIGIBILITY FOR LICENSE

POLICE STATIONS. - Authorization for the various classes of police stations will be issued only to instrumentalities of government.

MARINE FIRE STATIONS. - Authorizations for marine fire stations will be issued only to municipalities.

SPECIAL EMERGENCY STATIONS. - Authorizations for special emergency stations will be issued only to (a) organizations established for relief purposes in emergencies and which have a disaster communication plan; (b) to persons having establishments in remote locations which cannot be reached by other means of communication; (c) to public utilities.

FORESTRY STATIONS. - Authorizations for forestry stations will be issued to municipal, State, or private organizations which are legally responsible for the protection of forest areas.

APPLICATIONS

INDIVIDUAL AND BLANKET APPLICATIONS. - Individual applications for instruments of authorization shall be submitted for each station to be located at a fixed location. Blanket applications for authorizations for identical mobile, portable-mobile, or low powered portable transmitters, submitted by a single applicant to cover equipment to be used in a single coordinated communication system will be accepted. A blanket application may be submitted by a single applicant for a license or modification of license, covering both the land transmitter and mobile, portable-mobile, or low powered portable transmitters used in a single coordinated communication system.

FREQUENCIES

STATE AND MUNICIPAL POLICE STATIONS. - The following frequencies are allocated for use by State and municipal police stations:

1610 kc	1690 kc	2382 kc	2458 kc
1626 kc	1698 kc	2390 kc	2466 kc
1634 kc	1706 kc	2406 kc	2474 kc
1642 kc	1714 kc	2414 kc	2482 kc
1658 kc	1722 kc	2422 kc	2490 kc
1666 kc	1730 kc	2430 kc	
1674 kc	2326 kc	2442 kc	
1682 kc	2366 kc	2450 kc	

STATE AND MUNICIPAL ADDITIONAL UNLIMITED POWER. - (a) The following additional frequencies are allocated for use by land and portable municipal and State police stations without limitation as to power:

GROUP A

30700 kc	31900 kc	33940 kc	37500 kc	39900 kc
31100 kc	33100 kc	35500 kc	39100 kc	

(b) The following additional frequencies are allocated for use by land and portable municipal and State police stations operating with power not in excess of 250 watts:

GROUP B

31500 kc	35900 kc	37900 kc
33500 kc	37100 kc	39500 kc

(c) Notwithstanding the provisions of (a) and (b) of this section, municipalities and States may be authorized to operate mobile and portable-mobile stations on the frequency, or frequencies, assigned to their land station (s). An instrumentality of government operating mobile units only may be authorized to use a frequency from group A or group B of this section assigned an adjacent instrumentality of government, provided a copy of the agreement entered into between the two for the exchange of service is filed with the Commission.

(d) Municipalities and States desiring more than one land frequency shall, in making application, show a proper need therefor.

(e) Municipalities desiring frequencies for use by portable stations of 1 watt power or less, portable-mobile stations, or mobile stations different from those which may be allocated under section 10.42 (a) and (b), may be authorized to use the following frequencies:

GROUP C

30580 kc	31780 kc	33780 kc	35220 kc	37780 kc
30980 kc	33220 kc	35100 kc	37220 kc	39380 kc

(f) States desiring frequencies for use by portable-mobile or mobile stations different from those which may be allocated under section 10.42 (a) and (b), may be authorized to use the following frequencies. These frequencies are also available to states for portable stations of 1 watt power or less:

GROUP D

35780 kc	37380 kc	39180 kc	39780 kc

(g) The number of frequencies which may be assigned to any one municipality or State for either land, portable, or mobile stations will be governed pursuant to announced policies of the Commission.

SPECIAL ALLOCATION. - The frequency 190 kilocycles is allocated for use by State police stations for radiotelegraph communication for emergency use in the event of failure of police wire communication systems.

ZONE AND INTERZONE. - The following frequencies are allocated for zone and interzone police stations:

(a) For interzone communication subject to the condition that no interference is caused to international service (available to interzone police stations and to zone police stations designated as alternate interzone control stations):

5135 kc working	7480 kc day only
5140 kc working	7805 kc day only
5195 kc calling	7935 kc day only

(b) For zone communication (available to interzone and zone police stations):

2804 kc calling	2808 kc working	2812 kc working

(c) Calling frequencies herein allocated may be used for the transmission of operating signals and a single short radiotelegram provided no interference is caused to call signals.

MARINE FIRE STATIONS. - The following frequencies are allocated for use by marine fire stations:

1630 kc	35580 kc	37740 kc

SPECIAL EMERGENCY STATIONS. - The following frequencies are allocated to special emergency stations:

(a) For portable stations with a maximum power of 1 watt, portable mobile stations, and mobile stations:

31740 kc	33820 kc	37180 kc	39340 kc
33064 kc	35140 kc	37820 kc	

(b) For fixed, land, and portable stations without limitation as to power:

31460 kc   39660 kc   39860 kc

(c) For fixed, land and portable stations with a maximum power of 1000 watts:

2726 kc (A3 emission)   3190 kc (A1 emission)

(d) For fixed, land, and portable stations of public utilities, using A3 emission, with a maximum power of 50 watts:

2292 kc   4637 kc day only

(e) Notwithstanding the provision of (b), (c), and (d) of this section authorizations may be issued covering the operation of mobile and portable-mobile stations on the frequency, or frequencies, assigned to licensees of fixed or land stations.

FORESTRY STATIONS. - The following frequencies are allocated to forestry stations:

(a)

30940 kc	39740 kc	35940 kc	31580 kc	31940 kc
35740 kc	31340 kc	39940 kc	37460 kc	39420 kc

(b) Maximum power 50 watts:

2212 kc   2236 kc   2244 kc

(c) Maximum power 500 watts:

2226 kc

ASSIGNED FREQUENCIES NONEXCLUSIVE. - No frequency available to a station in the emergency service will be assigned exclusively to any applicant. All stations in this service are required to coordinate operation so as to avoid interference and make the most effective use of the frequencies assigned.

OPERATING SPECIFICATIONS

PERCENT OF TOLERANCE. - The frequency tolerance of stations in the emergency service shall be as follows:

	Equipment authorized before Oct. 1, 1938	Equipment authorized after Oct. 1, 1938
	Percent	Percent
Fixed stations on frequencies below 30,000 kc.	0.03	0.01
Land stations on frequencies below 30,000 kc.	.04	.02
Portable and mobile stations on frequencies below 30,000.	.04	.02
Fixed and land stations on frequencies above 30,000 kc.	.05	.02
Portable and mobile stations on frequencies above 30,000.	.05	.03
Portable and mobile stations of 1 watt power or less on frequencies above 30,000 kc.	.1	.1

MODULATION LIMITS. - The transmitters of stations in the emergency services using A3 emission shall be modulated not less than 85 percent nor more than 100 percent on peaks.

FREQUENCY MEASUREMENT

MEASUREMENT PROCEDURE. - The licensee of each station shall provide for measurement of the frequency of the transmitter(s) and establish procedure for checking it regularly. These measurements of frequency shall be made by means independent of the frequency control of the transmitter and shall be of such an accuracy that the limit of error is within the frequency tolerance allowed the transmitter.

TEST

EQUIPMENT AND SERVICE TESTS. - Equipment and service tests as authorized in sections 2.24 and 2.43 may be conducted provided that the necessary precautions are taken to avoid interference. The equipment tests authorized by section 2.42 may be conducted only during daylight hours on frequencies below 6000 kcs.

ROUTINE TESTS. - The licensees of all classes of stations in the emergency service are authorized to make such routine tests as may be required for the proper maintenance of the station and communication network, provided that precautions are taken to avoid interference with any station in the particular service involved.

LICENSES

PERIOD. - The license period for all stations in the emergency service shall be for 1 year unless otherwise stated in the instrument of authorization. The date of expiration of license for all classes of stations operating in the emergency service, unless otherwise specified, shall be the 1st day of May of each year.

POSTING FIXED STATION LICENSES. - The station licenses of stations in this service, operated at fixed locations, shall be conspiculously posted at the place where the control operator is located.

POSTING PORTABLE OR MOBILE STATION LICENSES. - The licenses of portable and mobile stations, if separately issued, shall be readily available for inspection by authorized Government representatives. Either the original authorization or a photocopy of that document shall be available at the portable or mobile station involved.

OPERATOR LICENSE. - The original license of each station operator shall be conspicuously posted at the place he is on duty, or, in the case of portable or mobile units, be kept in his personal possession.

LOGS

CONTENTS. - Each licensee shall maintain adequate records of the operation of the station including (a) hours of operation; (b) nature and time of each communication; (c) frequency measurements; (d) name of operator on duty at the transmitter. In the cases of groups of stations, either land or land and mobile, operating as a single coordinated communication system controlled from a single point, a single log may be maintained at a central location, provided that such log records the required information with respect to all stations in the network.

INSPECTIONS

INSPECTION BY COMMISSION'S REPRESENTATIVE. - All classes of stations in the emergency service shall be made available for inspection upon request of a representative of the Commission. However, if such station is actually engaged in an emergency which should not be interrupted, the Commissions representative may suspend the inspection and require the station to be made available for inspection immediately after conclusion of the emergency.

MUNICIPAL POLICE STATIONS

POWER. - The maximum power to be assigned for the use of frequencies below 30,000 kc. by municipal police stations will be based on the latest official population figures of the Department of Commerce for the area to be served in accordance with the following table:

Population:	Power watts
Under 100,000	50
100,000 to 200,000.	100
200,000 to 300,000	150
300,000 to 400, 000.	200
400,000 to 500,000.	250
500,000 to 600,000.	300
600,000 to 700,000	400
Over 700,000.	500

ADDITIONAL POWER. - In the event that the amount of power allocated above is insufficient to afford reliable coverage over the desired service area, the Commission may authorize the use of additional stations of the same or less power, or upon proper showing being made, may authorize such additional power as may be necessary, but not to exceed 500 watts: Provided, However, That municipal police stations authorized to serve an entire county under the providions of section 10.123, may be licensed to employ a maximum power of 1,000 watts between 1 hour after local sunrise and 1 hour before local sunset, on condition that the applicant files with the application an agreement, entered into with other licensees operating on the same frequency and in the same area to which the frequency is assigned, including a statement giving their consent to the use of such increased power; and that such agreement shall provide for notification to the Commission 60 days prior to termination thereof.

COOPERATIVE SERVICE. - An application for an authorization for a municipal police station to serve two or more municipalities shall be supported by sworn copies of agreements made between the proposed licensee and the contiguous municipalities. Such agreements shall show that the applicant is required to furnish emergency police radio service to the contiguous municipalities and that the contiguous municipalities agree to accept such service and not to request individual authority to operate municipal police radio transmitting stations, and that such agreements shall provide for notification to the Commission 60 days prior to termination thereof.

COOPERATIVE USE OF FREQUENCIES. - The frequencies allocated to municipal police stations are assigned for use within specified geographical boundaries and all licensees within those boundaries shall cooperate in the use of the assigned frequency.

SERVICE WHICH MAY BE RENDERED. .- Municipal police stations, although licensed primarily for communication with mobile police units, may transmit emergency messages to other mobile units such as fire department vehicles, private ambulanees, and repair units of public utilities, in those cases which require cooperation of coordination with police activities. In addition, such stations may communicate among themselves provided (1) that no interference is caused to the mobile service, and (2) that communication is limited to places between which, by reason of their close proximity, the use of police radiotelegraph station is impracticable. Municipal police stations shall not engage in point-to-point radiocommunication beyond the good service range of the transmitting station. The transmission or handling of messages requiring radiotelephone relay or the relaying of such messages is prohibited; Provided, however, That after proper showing and in unusual circumstances the Commission may in specific instances authorize communication routes involving such relays. Point-to-point communication between stations in the same local telephone exchange area is like wise prohibited unless the messages to be transmitted are of immediate importance to mobile units.

STATE POLICE STATIONS

POWER. - The maximum power to be assigned for the use of State police stations shall be 5,000 watts during the period from sunrise to sunset and 1,000 watts from sunset to sunrise

SERVICE WHICH MAY BE RENDERED. - State police stations, although licensed primarily for communication with mobile police units may transmit emergency messages to other mobile units such as fire department vehicles, private ambulances and repair units of public utilities, in those cases which require cooperation or coordination with police activities. In addition, such stations may communicate among themselves provided (1) that no interference is caused to the mobile service, and (2) that communication is limited to places between which, by reason of their close proximity, the use of police radiotelegraph stations is impracticable. State police stations shall not engage in point-to-point radiocommunication beyond the good service range of the transmitting station. The transmission or handling of messages requiring radiotelephone relay or the relaying of such messages is prohibited; Provided, however, That after proper showing and in unusual circumstnnces the Commission may in specific instances authorize communication routes involving such relays. Point-to-point communication between stations in the same local telephone exchangee area is likewise prohibited unless the messages to be transmitted are of immediate importance to mobile units.

INTERZONE POLICE STATIONS

ONE STATION PER ZONE. - Authorizations for interzone police stations will not be issued for more than one station within a zone.

ELIGIBILITY FOR LICENSE. -- In general only the licensees of state and municipal police stations may be granted authorizations to operate interzone police stations.

EQUIPMENT. -- Authorization for interzone police stations may be granted specifying equipment authorized for use by municipal or state police stations provided that the radiotelegraph use of such equipment is on a secondary basis, and that the equipment is so designed that the frequency can be changed without delay.

POWER. -- The maximum power to be assigned for the use of interzone police stations shall be 500 watts.

SERVICE WHICH MAY BE RENDERED. -- Interzone police stations shall be operated only for the transmission of dispatches of an emergency nature relating to police business between police agencies, using the operating procedure prescribed by the Commission.

OPERATOR REGULATIONS. -- The records and method of operation of interzone police stations shall be maintained and conducted in accordance with the operating procedure prescribed by the Commission.

ZONE POLICE STATIONS

ELIGIBILITY FOR LICENSES. -- In general only the licensees of state and muncipal police stations may be granted authorizations to operate zone police stations.

EQUIPMENT. -- Authorizations for zone police stations may be granted specifying equipment authorized for use by municipal or state police stations provided that the radiotelegraph use of such equipment is on a secondary basis and that the equipment is so designed that the frequency can be changed without delay.

POWER. -- The maximum power to be assigned for the use of zone police stations shall be 500 watts.

SERVICE WHICH MAY BE RENDERED. -- Zone police stations shall be operated only for the transmission of dispatches of an emergency nature relating to police business between police agencies, using the operating procedure prescribed by the Commission.

OPERATOR REGULATIONS. -- The records and method of operation of zone police stations shall be maintained and conducted in accordance with the operating procedure prescribed by the Commission.

ALTERNATE ZONE CONTROL STATIONS. -- Zone police stations may be designated to act as alternate zone control stations for the interzone stations designated for the zone concerned; in which event, such zone police stations shall be eligible to be assigned all of the frequencies abailable for interzone police stations.

MARINE FIRE STATIONS

POWER. -- The maximum power to be assigned for the use of marine fire stations will be 500 watts.

SERVICE WHICH MAY BE RENDERED. -- Marine fire stations are licensed primarily for intercommunication between fire headquarters and fireboats. However, they may transmit emergency messages to police boats or other marine units in cases which require cooperation or coordination with police or fire department activities.

SPECIAL EMERGENCY STATIONS

SCOPE OF SERVICE. -- (a) Special emergency stations may be used only during an emergency jeopardizing life, public safety, or important property;

(1) for essential communications arising from the emergency;

(2) for emergency transmission from one point to another between which normal communication facilities do not exist, are not usable, or are temporarily disrupted or inadequate.

(b) The use of special emergency stations for the handling of routine or non-emergency communications is strictly prohibited.

(c) Within the scope of service given in paragraph (a) the licensee of a special emergency station shall make the communication facilities of such station available to any member of the public.

(d) Special emergency stations, except those of communications common carriers utilized temporarily to restore normal public communications service disrupted by an emergency, shall not operate as common carriers of communications for hire. However, the licensees of such stations may accept contributions to capital and operating expenses from others who, under the Commission's rules, would be eligible to stations of their own, for the cooperative use of the stations on a cost-sharing basis; Provided, That contracts for such cooperative use are submitted to the Commission 30 days prior to the effective date thereof and that said contracts are not disapproved by the Commission.

SELECTIVE CALLING SYSTEM. -- Notwithstanding the provisions of section 10.46 (c) and (d), types Al or A2 emission may be used on 2726, 2292, and 4637.5 kc. for the sole purpose of establishing a selective calling system.

TESTS. -- Special emergency stations may also conduct routine tests not exceeding 2 minutes in each half hour, or, where more extended tests are required they may not exceed a total of 4 hours per week.

AVOIDANCE OF INTERFERENCE. -- Special emergency stations shall take all reasonable precautions, including listening tests, to avoid any possible interference to the service of another station.

FORESTRY STATIONS

SCOPE OF SERVICE. -- Forestry stations, although licensed primarily for communication with mobile forest fire fighting units, may transmit emergency messages to other mobile units such as fire department vehicles, private ambulances, and mobile police units in those cases which require cooperation or coordination with forestry service activities. In addition, such stations may communicate among themselves, Provided (1) no interference is caused to mobile service, and (2) only those communications are transmitted which are necessary for the operation of the forestry service.

INSTRUCTIONS--EMERGENCY SERVICE
(Revision of November 1, 1940)

1. In connection with the adoption of rules and regulations governing the emergency service, the Commission made the following statement with regard to the standards by which it will be governed in acting upon applications for authorizations in this service:

2. Section 10.31 provides for the submission of blanket applications for authorizations for identical stations. It is contemplated that, in general, mobile, portable-mobile, and low-powered portable transmitters operating as part of a coordinated communication system will not be assigned

individual licenses. Individual land stations in such a system will be individually licensed and will have separate call letters. The mobile and low-powered portable transmitters will be authorized in the license of the station normally in control of the communication network. Separate authorizations must be obtained for transmitters which are to be operated independently. In this respect your attention is invited to the provisions of Section 1.351 of the Commissions Rules, which requires that applications for instruments of authorization for land and fixed stations be submitted in duplicate. It should be noted that under the provisions of this section applications for portable and mobile transmitters are also to be submitted in duplicate. This is a change from previous practice.

3. Where application for license or modification of license for land and mobile equipment is made at the same time the description of the mobile equipment should appear on the same forms submitted for land station.

4. Applications for licenses filed with the application for construction permit will not be accepted unless a showing is made that the equipment described in the construction application is purchased as a complete unit and is of such a nature that no construction other than installation (connection with power supply and antenna) is necessary. If such a showing is made the application for license will be accepted, provided that all data, such as manufacturer's serial number, is supplied. Attention is particularly invited to Section 319 (a) of the Communications Act of 1934 as amended. It should be noted that there is no advantage gained by simultaneous filing in view of the service test permitted under section 10.71, discussed below.

5. Any failure by the applicant to conform to these requirements will necessitate the return of applications. This causes a needless delay in consideration of applications and issuance of authorizations. The applicant should, therefore, exercise care in submitting future applications in order to insure prompt action on the part of the Commission.

6. Requests for authority to install identical transmitting units may be made in a single application for construction permit. All units which are to be intended for service should be included whether they are destined for immediate installation or for spares. If two or more types of equipment are to be purchased a separate application for construction permit, in duplicate, is to be submitted for each type. In filing an application for license, or modification of license, identifying numbers of the transmitting units involved must be specified. If no serial number has been provided by the manufacturer, the applicant must assign and permanently affix a number to each transmitting unit. The license, when issued, will show the numbers of all transmitters authorized to be used. The Commission and the Inspector in Charge of the district in which the station is located are to be notified by letter at any time any unit is permanently retired from service either through destruction or obsolescense. Such units will be formally deleted from the license at the time a new license is issued. After a license has once been issued, if it is desired to add units, such units must first be authorized by construction permit and subsequently an application for modification of license must be filed to cover the operation of those units. Under these circumstances it is contemplated that the authorization for the additional units will be covered by a rider to the original license rather than by the issuance of a new license. At the time of renewal the identifying numbers of the added units will be included on the renewed license.

7. The purpose of a log is to present an adequate picture of the occupancy of a frequency. Section 10.101 provides that a log of the complete system may be maintained at the control point. This is not considered to mean that a system such as exists in some State police organizations in which a number of stations are involved and in which each of these stations has considerable independence may maintain its log at a central station. Under these circumstances,

each station must maintain its own records.

8. Special mention is made in section 10.48 of the responsibility of licensees in the emergency service to cooperate in the use of frequencies. It is expected that, in general, interference problems will be settled by cooperation between the various stations involved without reference to the Commission. The Commission will be glad to cooperate to any reasonable extent in matters of this kind and in case of failure to obtain a mutually satisfactory agreement, it may be necessary to hold a formal hearing.

9. In the assignment of frequencies below 3000 kilocycles to municipal and State police stations, the Commission has established an allocation plan which is designed to permit the expansion of the use of police radio facilities without the necessity of reallocation. The frequency allocated to any particular municipality or area may be obtained by communicating with the Washington offices of the Commission. Variations in this allocation plan cannot be made without serious disruptions to the police radio service, and, therefore, should not be requested.

10. The attention of municipalities on the borders of the United States is invited to Article 7 of the "Inter-American Agreement - Santiago, Chile, 1940," which reads as follows:

ARTICLE 7

INTERNATIONAL POLICE SERVICES

1. When the signatory countries authorize their police stations which are located in close proximity to the national boundaries of contiguous countries to transmit emergency information with similar stations of another country, the following rules shall be applied:

(a) Only police stations located close to the boundaries of contiguous countries shall be allowed to engage in this exchange of information.

(b) In general, only important police messages are to be handled, such as those which would lose their value due to slowness and time limitations of other communication systems.

(c) The frequencies to be used in radiotelephone communications with mobile police units shall not be used for radiotelegraph communications.

(d) Whenever the exchange of radiotelephone communications is authorized, these communications shall be made on the frequencies assigned to the respective stations for radiotelephone service.

(e) If the exchange of radiotelegraph communications is authorized, these communications shall be made on the following frequencies:

2804 kc calling	5195 kc day calling
2808 kc working	5135 kc day working
2812 kc working	5140 kc day working

(f) Notifications concerning the particulars of stations engaged in international police service shall be forwarded to the Bureau of International Telecommunications Union, Berne, Switzerland, in order that all stations desiring to intercommunicate may be kept informed of the details concerning their operations.

(g) This service shall, in general, conform with the provisions of article 17 of the Cairo Radio Regulations.

(h) Full use shall be made of the list of abbreviations appearing in appendix 11 to the Cairo Radio Regulations. Plain language shall not be used if abbreviations will suffice.

Service indications are as follows: "P", priority for messages that are to be sent immediately, regardless of the number of other messages on file, If no service indication is given th messages are to be transmitted in the order of receipt.

(i) The message shall contain the preamble, text, and signature, as follows:

(1) PREAMBLE. - The preamble of the massage shall consist of the following: the serial number preceded by the letters "NR";. service indications as appropriate; check (this is the group count according to standard cable count system); the letters "CK" followed by mumerals indicating the number of words contained in the text of the message; office and country of origin (not abbreviated) day of month and month, hour of filing and address.

(2) TEXT - The text may be either in plain language or code.

(3) SIGNATURE. - The signature shall include the name and title of the person originating the message.

11. Those municipalities interested in communicating internationally must request authority from the Commission, including in the request all the particulars as required in paragraph (f) of this article. If authority is granted the Commission will notify the Berne Bureau and other governments.

12. The Commission recognizes the various factors affecting the propagation of radio emis sions, as well as the variations in operating conditions which may be expected in this service Subject to these considerations the following provisional standards are adopted for the guidance of applicants for facilities in the frequency bands above 30,000 kilocycles:

(a) The frequencies in group A (section 10.42) are allocated primarily only to states and municipalities serving large geographic areas under conditions requiring the use of power in excess of 250 watts. However, they will also be available to stations requiring less power provided that if interference situations should arise, the priority of the high-powered stations must be recognized. In general, the frequencies in this group will be assigned only to densely populated areas having a radious of 5 miles or more. Only one frequency in this group will be assigned to municipalities actually operating 100 cars or less.

(b) The frequencies in group B are available for states and for cities serving areas smaller than the above. Only one of these frequencies will be assigned any municipality operating 100 or less cars.

(c) The frequencies from group C will be assigned to municipalities on the basis of one frequency for each 50 mobile or portable-mobile units included in the municipality communication system.

13. The Commission expects that licensees and applicants for facilities above 30,000 kilocycles will arrange for the proper choice and use of frequencies to minimize interference in any area, prior to the filing of applications. The Commission may specify the frequency, or frequencies, which may be assigned, and prescribe the manner of their use.

14. Before an application, specifying frequencies above 30 megacycles, is submitted to the Commission each municipality or state is to communicate with all licensees of police stations operating in 30 to 40 megacycle band within a radius of approximately 40 miles of the location of the proposed station and cooperatively agree upon the selection of frequencies. States applying for frequencies in group D of section 10.42 are exempt from this requirement. A copy of all such agreements forumlated must be filed with the application. Such documents may take the form of letters addressed to the Commission from the surrounding licensees stating that they have no objection to the applicant's use of the requested frequency. If, as a result of the applicant's investigation, there are no other stations of this category within the area mentioned above, a statement to this effect must accompany the application.

In congested areas where associations have been formed for the purpose of cooperating in the use of ultra high frequencies, a clearance from such a group will be satisfactory in lieu of agreements from each licensee. However, if all the nearby licensees do not belong to the association for a particular area, the individual agreements should be submitted to the Commission from non-members as well as the approval from the association for the applicant's use of the requested frequency.

15. Applicants for facilities above 30,000 kilocycles will be required to include as a part of their applications a complete statement as to the result of the investigation made necessary by the paragraph next above and attach to their applications or identify by reference to documents on file with the Commission any agreements that may have been entered into, affecting police radio operation in the geographical area in which applicant's facilities will be located.

16. It is not desired to be more specific with respect to the uses to which special emergency stations may be put than is set forth in section 10.231. In using these facilities it should be realized that the frequencies assigned thereto are few in number and must be shared among various licensees. A routine dispatching service is not permitted nor is a private point-to-point transmission or routine messages appropriate. Licensees may be required to justify the emergency character of any message transmitted should its priority be questioned.

17. As the rules indicate, the operation of forestry stations must be strictly limited to the needs of forest protection. In the interest of such protection, as well as in the interest of reduction of interference, the operations of forestry stations in any single geographical area should be coordinated. Therefore, applicants for forestry station facilities, other than State forestry organizations, will be required to include as a part of their applications a statement as to whether the State in which the proposed station is to be located has a department for forest protection, and if such a department exists, the applicant shall submit a copy of the cooperative agreement between the applicant and the state department concerned, or lacking such agreement, the applicant shall submit copies of the correspondence exchanged between them in an effort to reach a cooperative agreement. One submission on part of any applicant of information with regard to any one coordinated plan as specified in this paragraph will suffice, provided that reference thereto is made in all other applications involved in the plan.

18. If licensed operators are not to be used on the portable-mobile units of a police radiocommunication system, there must be on duty at all times at the land station an operator holding a second-class license or higher, who has actual control of the portable-mobile units and personnel therein, and who has the authority to order the portable-mobile units off the air at any time necessary either for technical or other reasons, in order to insure proper operation. If operators holding only restricted radiotelephone permits are employed at the a land station then an operator holding at least a restricted radiotelephone permit must be employed on each of the cars at all times the equipment is in use. (See section 2.53 (a) (2)). In any event service and maintenance of the transmitting equipment may be conducted only by personnel holding second-class or higher, licenses. In the interest of continuity of service, if such an operator is not regularly employed at the radio station, he should be immediately available. 9 (See sections 13.61 (e) (3) and 13.75)

CHAPTER XII

RULES GOVERNING BROADCAST SERVICES OTHER THAN STANDARD BROADCAST

Frequency tolerance. - The operating frequency of the broadcast stations as listed below shall be maintained within plus or minus the percentage of the assigned frequency as given in Table 1.

TABLE 1.

Class of station	Frequency tolerance
Relay broadcast station:	
(a) 1622 to 2830 kc.	0.04 percent
(b) 30,000 to 40,000 kc and above.	10 watts or less, 0.1 percent Above 10 watts, 0.05 percent
St broadcast station.	0.01 percent
International broadcast station	0.005 percent
Television broadcast station.	0.01 percent
Facsimile broadcast station.	0.05 percent or less as required
High frequency broadcast station.	0.01 percent
Noncommercial educational broadcast station.	Do.
Developmental broadcast station.	0.05 percent or less as required.

(Tolerance may be 0.01 percent on equipment installed prior to Jan. 1, 1940, when all international stations shall maintain frequency within 0.005 percent of the assigned frequency.)

Frequency monitors. (a) The licensee of each broadcast station listed in section 4.1 except relay broadcast stations, shall operate at the transmitter a frequency monitor independent of the frequency control of the transmitter. (b) The frequency monitor shall be designed and constructed in accordance with good engineering practice and shall have an accuracy sufficient to determine that the operating frequency is within one-half (1/2) of the allowed tolerance. (c) The licensee of each relay broadcast station shall provide the necessary means for determining that the frequency of the station is within the allowed tolerance. (d) The frequency of all stations listed in Table 1, shall be checked at each time of beginning operation and as often thereafter as necessary to maintain the frequency within the allowed tolerance.

License period; renewal. - (a) Licenses for the following classes of broadcast stations normally will be issued for a period of 1 year expiring as follows:

Class	Date of expiration
ST broadcast station.	Apr. 1
International broadcast station.	Nov. 1
Television broadcast station.	Feb. 1
Facsimile broadcast station.	Mar. 1
High frequency broadcast station.	Apr. 1
Noncommercial educational broadcast station.	May 1
Development broadcast station.	May 1

(b) Licenses for the following class of broadcast station normally will be issued for a period of two years expiring as follows:

Class of station	Date of expiration
Relay broadcast station:	
(a) 1622 to 2830 kc.	Oct. 1 (even years)
(b) 30,000 to 40,000 kc and above.	Dec. 1 (odd years)

(c) Each licensee shall submit the application for renewal of license at least 60 days prior to the expiration date (section 1.360).
(d) A supplemental report shall be submitted with each application for renewal of license of a station licensed experimentally in accordance with the regulations governing each class of station.

Requirements, limitations, and restrictions. - (a) No station licensed experimentally will be assigned for exclusive use of any frequency. In case interference would be caused by simultaneous operation of stations licensed experimentally, such licensees shall endeavor to arrange satisfactory time division. If such agreement cannot be reached, the Commission will determine and specify the time division.
(b) The Commission may from time to time require that a station licensed experimentally conduct such experiments that are deemed desirable and reasonable for the development of the service.
(c) The program of research and experimentation as offered by an applicant in compliance with the requiremtnts for obtaining a license for an experimental station shall be adhered to in the main, unless the licensee is authorized to do otherwise by the Commission.
(d) A licensee of an experimental station is not required to adhere to a regular schedule of operation but shall actively conduct a program of research and experimentation or transmission of programs: Provided, however, Licensees of developmental broadcast stations which are licensed to conduct special intermittent experiments, such as to develop and test commercial broadcast equipment, are required to operate only when there is a need therefore.
(e) A supplementary statement shall be filed with and made a part of each application for construction permit for any broadcast station on an experimental basis which specifies any frequency above 300,000 kilocycles or in the bands 162,000, 210,000 and 264,000 to 270,000 kilocycles except television, confirming the applicant's understanding:

(1) That all operation upon the frequency is experimental only,
(2) That the frequency may not be the best suited to the particular experimental work to be carried on, and
(3) That the frequency may not be allocated for the service that may be developed experimentally.

Station records - (a) The licensee of each class of broadcast station listed in Table 1. shall maintain adequate records of the operation including:

(1) Hours of operation
(2) Program transmitted
(3) Frequency check
(4) Pertinent remarks concerning transmission
(5) In case of relay station, an entry giving point of program origination and receiver location shall be included
(6) Research and experimentation conducted in case of an experimental station
(7) And any additional information specified in the regulations governing each class of

station or for completing the supplemental report as required.
(b) The above information shall be made available upon request by authorized Commission representatives.

Equipment changes. -- The licensee of each class of broadcast station listed in Table I may make any changes in the equipment that are deemed desirable or necessary, Provided:
(a) That the operating frequency is not permitted to deviate more than the allowed tolerance;
(b) That the emissions are not permitted outside the authorized band;
(c) That the power output complies with the license and the regulations governing the same;
(d) That the transmitter as a whole or output power rating of the transmitter is not changed.

Emission authorized. -- All classes of broadcast licenses authorize A3 emission only unless otherwise specified in the license. In case A1, A2, A4, A5, or special emissions are necessary or helpful in carrying on any phases of experimentation, application setting out fully the needs shall be made to, and authority therefor received from, the Commission.

Additional orders, as needed. -- In case all the general rules and regulations and the specific rules governing each class of broadcast station do not cover all phases of operation or experimentation with respect to external effects, the Commission may make supplemental or additional orders in each case as deemed necessary for operation in the public interest, convenience, and/or necessity.

Operation. -- A licensed operator shall be on duty and in charge of the transmitter of each broadcast station listed in Table I. In no case will remote control operation be authorized. A transmitter is not considered as being operated by remote control when the following conditions prevail:
(a) Continuous reading indicating instruments are before the operator as follows:
(1) Frequency deviation meter.
(2) Percentage modulation indicator.
(3) Spurious emission check (receiver).
(4) Last radio stage plate voltage.
(5) Last radio stage total plate current.
(6) Output or antenna current.
(b) The operator has off-and-on control of the last radio stage.
(c) The operator can reach the transmitter proper in not more than 5 minutes to make any changes or adjustments necessary to maintain proper operation.

Rebroadcasts. -- (a) The licensee of an international or noncommercial educational broadcast station may, without further authority of the Commission, rebroadcast the program of a United States standard broadcast station, Provided the Commission is notified of the call letters of each station rebroadcast and the licensee certifies that express authority has been received from the licensee of the station originating the program.

(b) No licensee of an international broadcast station shall rebroadcast the program of any other class of United States radio station without written authority having first been obtained from the Commission.

(c) The licensee of a noncommercial educational broadcast station may, without further authority of the Commission, rebroadcast the noncommercial programs of a standard broadcast station or an international broadcast station, provided the Commission is notified of the call letters of each station rebroadcast and the licensee certifies that express authority has been received from the licensee of the station originating the program

(d) No licensee of any other class of broadcast station listed in Table I (television, facsimile, high-frequency or developmental) shall rebroadcast the program of any radio station without written authority first having been obtained from the Commission.

(e) A licensee of an international broadcast station may authorize the rebroadcast of its programs by any station outside the limits of the North American Continent without permission from the Commission: Provided, That, the station rebroadcasting the programs cannot be received consistently in the United States.

(f) An application for authority to rebroadcast the program of any radio station shall be accompanied by written consent or certification of consent of the licensee of the station originating the program.

Equipment and program tests. -- (a) A licensee of a broadcast station listed in Table I shall conduct equipment tests in accordance with section 2.42 and program tests in accordance with the following section.

(b) In case the transmitter and associated equipment are on hand in complete for and an application for license was filed and branted with the application for construction permit, then the notification of equipment tests and program tests as required by paragraph (a) of this section need not be made.

Station and operator licenses; posting of. -- (a) The station license and any other instrument of authorization or individual order concerning the construction of the equipment or manner of operation of the station shall be posted so that all terms thereof are bisible in a conspicuous place in the room in which the transmitter is located: Provided:

(1) If the transmitter operator is located at a distance from the transmitter pursuant to section 4.9, the station license shall be posted in the above described manner at the operating position.

(2) If the station is licensed for portable-mobile operation, the station license or a photo copy thereof shall be affixed to the equipment or kept in the possession of the operator on duty at the transmitter. If a photo copy is used, the original license shall be available for inspection by an authorized government representative.

(b) The license of each station operator(s) shall be conspicuously posted at the operating position, Provided:

(1) If the station at which the operator is on duty is licensed for portable-mobile operation, the operator's license may be kept in his personal possession.

RELAY BROADCAST STATIONS

Defined. -- The term "relay broadcast station" means a station licensed to transmit from points where wire facilities are not available, programs for broadcast by one or more broadcast stations, or orders concerning such programs.

Licensing and authorizations. -- (a) A license for a relay broadcast station will be issued only to the licensee of a standard broadcast station: Provided, however, In cases where it is impractical, impossible, or prohibited by laws or regulations for the licensee of a standard broadcast station to install, operate or maintain the necessary equipment under its legal control, the Commission may grant special temporary authority for each event to another person to operate as a relay broadcast station equipment already licensed for another service, or equipment which may be installed under section 319 (b) of the Communications Act of 1934 without a construction permit: and provided further:

(b) The Commission may license a special relay broadcast station to the licensee of another class of broadcast station provided a need therefore is shown and the relay station will be used only for relaying of programs for broadcast by such broadcast station

(c) The license of a relay broadcast station authorizes the transmission of commericial or sustaining programs, or orders concerning such programs, to be broadcast by its standard broadcast station and other broadcast stations transmitting the same programs simultaneously or a chain program to the network with which the licensee is regularly affiliated. The license of a relay station does not authorize transmission of programs to be broadcast solely by other broadcast stations not aforementioned.

(d) In case a licensee has two or more standard broadcast stations located in different cities, it shall, in applying for a new relay station or for renewal of license of an existing relay station, designate the standard broadcast station or stations in conjunction with which the relay station is to be operated principally, and it shall not thereafter operate the relay station in conjunction with another of its standard broadcast stations located in a different city for more than a total of 10 days in any 30-day period.

(e) Each application for temporary authority to operate a relay broadcast station from a person other than a licensee of a standard broadcast station shall be accompanied by an application for authority to broadcast the program from the licensee of the standard broadcast station proposing the broadcast.

(f) An application for special temporary authority to operate another class of station as a relay broadcast station shall specify a group of frequencies allocated in the following section: Provided, however, In case of events of national interest and importance which cannot be transmitted sucessfully to the nearest available wire facilities on these frequencies other frequencies under the jurisdiction of the Commission may be requested, if it is shown that the operation thereon will not cause interference to established stations.

(g) An application for special temporary authority to operate on frequencies not allocated by the section below,.or to operate another class of station as a relay broadcast station shall be specified by the Commission not less than 10 days prior to the actual event to be broadcast, and shall contain complete information concerning the frequencies requested, and the license of the station to be used. In case of emergencies, which shall be fully explained in the application, the Commission may waive the 10-day requirement specified herein.

Frequency assignment and operation. -- The following groups of frequencies are allocated for assignment to relay broadcast stations:

Group A Kilocycles	Group B Kilocycles	Group C Kilocycles	Group D Kilocycles	Group E Kilocycles
1622	1606	1646	30820	31200
2058	2074	2090	33740	35620
2150	2102	2190	35820	37020
2790	2758	2830	37980	39260

Group F Kilocycles	Group G Kilocycles	Group H Kilocycles	Group I Kilocycles	Group J
31620	33380	156075	156750	Any 4 frequencies above 300,000 kc excluding band 400,000 to 401,000
35260	35020	157575	158400	
37340	37620	159975	159300	
39620	39820	161925	161100	

(b) One of the above groups only, including all four frequencies, will be assigned each station. The first application from any metropolitan area for the frequencies in groups A,B, or C shall specify group A; the second, group B; and the third group C; the fourth group A again, etc., Outstanding assignments not following this order will not be changed unless a need therefor develops. Additional applicants shall specify the next unassigned group in sequence or any other group if it appears interference will be avoided thereby.

(c) A station may be licensed for group H when a need for frequencies of this order may be shown.

(d) Group I will be licensed to stations to operate with frequency modulation only when need for such operation and frequencies of this order may be shown.

(e) Any four specific frequencies under group J will be assigned on experimental operation only and an applicant may apply for the four frequencies which appear most suitable for the expermental work to be conducted.

(f) The licensee of a station in group J shall carry on research and experimentatation for the advancement of the relay broadcast art and development of these ultra high frequencies for relay broadcast services. An application for authority to operate a station on frequencies in group J shall include a statement concerning the research and experiments to be conducted. The research and experiments shall indicate reasonable promise of substantial contribution to the development of the program relay services.

(g) A license authorizes operation on only one of the four assigned frequencies at any one time. In case it is desired to transmit programs and spoken orders concerning such programs simultaneously, two licenses are required though each may specify the same group of frequencies.

Frequency selection to avoid interference. -- In case two or more stations are licensed for the same group of frequencies in the same area and in case simultaneous operation is contemplated, the licensees shall endeavor to select frequencies to avoid interference. If a mutual agreement to this effect cannot be reached, the Commission shall be notified and it will specify the frequencies on which each station is to be operated.

Power limitations. -- (a) A relay broadcast station assigned frequencies in Groups A,B,C, and J will be licensed to operate with a power output not in excess of that necessary to transmit the program and orders satisfactorily to the receivers and shall not be operated with a power greater than licensed.

(b) A relay broadcast station assigned frequencies in groups D,E,F, and G will not be authorized to install equipment or licensed for an output power in excess of 100 watts; Provided, That before using any frequency in these groups with a power in excess of 25 watts, tests shall be made by the licensee to insure that no objectionable interference will result to the service of any government station, and Provided further, That if the use of any frequency may cause interference then the power shall be reduced to 25 watts or another frequency in the licensed group selected which will not cause objectionable interference.

(c) A relay broadcast station assigned frequencies in groups H and I will be licensed to operate with a power output not in excess of that necessary to transmit the program and orders satisfactorily to the receivers and shall not be operated with a power greater than that licensed. In the event interference may be caused to stations on adjacent channels, licensees shall endeavor to make arrangements to reduce power to a point where interference will not be objectionable. If a satisfactory arrangement cannot be agreed upon, the Commission will determine the maximum power or conditions of operation of each such station.

Supplemental report with renewal application. -- The licensee of a relay broadcast station assigned frequencies under group J shall submit a supplemental report with and made a part of each application for renewal of license as follows:

(a) Number of hours operated for experimental purposes.
(b) Developments carried on in the relay broadcast service.
(c) Propagation characteristics of the frequencies assigned with regard to relay broadcast service.
(d) All developments or major changes in equipment.
(e) Any other pertinent developments.

INTERNATIONAL BROADCAST STATIONS

Defined. -- The term "international broadcast station" means a station licensed for the transmission of broadcast programs for international public reception. (Frequencies for these stations are allocated from bands assigned between 6000 and 26,600 kilocycles for broadcasting by international agreement.)

Licensing requirements; necessary showing. -- A license for an international broadcast station will be issued only after a satisfactory showing has been made in regard to the following, among others:

(a) That there is a need for the international broadcast service proposed to be rendered.

(b) That the necessary program sources are available to the applicant to render an effective international service.

(c) That the technical facilities are available on which the proposed service can be rendered without causing interference to estabilished international stations having prior registration and occupancy in conformity with existing international conventions or regulations on the frequency requested.

(d) That directive antennas and other technical facilities will be employed to deliver maximum signals to the country or countries for which the service is designed.

(e) That the production of the program service and the technical operation of the proposed station will be conducted by qualified persons.

(f) That the applicant is technically and financially qualified and possesses adequate technical facilities to carry forward the service proposed.

(g) That the public interest convenience and necessity will be servied through the operation of the proposed station.

Service; commercial or sponsored programs. -- (A) A licensee of an international broadcast station shall render only an international broadcast service which will reflect the culture of this country and which will promote international good will, understanding, and cooperation. Any program solely intended for, and directed to an audience in the continental United States does not meet the requirements for this service.

(b) Such international broadcast service may include commercial or sponsored programs: Provided, That:

(1) Commercial program continuities give no more than the name of the sponsor of the program and the name and general character of the commodity, utility or service, or attraction advertised.

(2) In case of advertising a commodity, the commodity is regularly sold or is being promoted for sale on the open market in the foreign country or countries to which the program is directed in accordance with paragraph (c) of this section.

(3) In case of advertising an American utility or service to prospective tourists or visitors to the United States, the advertisement continuity is particuarly directed to such persons in the foreign country or countries where they reside and to which the program is directed in accordance with paragraph (c) of this section.

(4) In case of advertising an international attraction (such as a world fair, resort, spa, etc.) to prospective tourists or visitors to the United States, the oral continuity concerning such attraction is consistent with the purpose and intent of this section.

(5) In case of any other type of advertising, such advertising is directed to the foreign country or countries and to which the program is directed in accordance with paragraph (c) of this section and is consistent with the purpose and intent of this section.

(c) The areas or zones established to be served by international broadcast stations are the foreign countries of the world, and directive antennas shall be employed to direct the signals to specific countries. The antenna shall be so designed and operated that the signal (field intensity) towards the specific foreign country or countries served shall be at least 3.16 times the average effective signal from the station (power gain of 10).

(d) An international broadcast station may transmit the program of a standard broadcast station or network system: Provided, the conditions in paragraph (b) of this section in regard to any commercial continuities are observed and when station identifications are made, only the call letters designation of the international station is given on its assigned frequency; And Provided further, That in the case of chain broadcasting the program is not carried simultaneously by another international station (except another station owned by the same licensee operated on a frequency in a different group to obtain continuity of signal service), the signals from which are directed to the same foreign country or countries.

(e) Station identification, program announcements, and oral continuity shall be made with international significance (language particularly) which is designed for the foreign country or countries for which the service is primarily intended.

(f) (1) Each licensee of an international broadcast station shall make verbatim mechanical records of all international programs transmitted.

(2) The mechanical records, and such manuscripts, transcrips, and translations of international broadcast programs as are made shall be kept by the licensee for a period of two years after the date of broadcast and shall be furnished the Commission or be available for inspection by representatives of the Commission upon request.

(3) If the broadcast is in a language other than English the licensee shall furnish to the Commission upon request such record and scripts together with complete translations in English.

Frequency assignment. -- (a) The following groups of frequencies are allocated for assignment to international broadcast stations:

Group A Kilocycles	Group B Kilocycles	Group C Kilocycles	Group D Kilocycles
6040	9530	11710	15130
6060	9550	11730	15150
6080	9570	11790	15210
6100	9590	11820	15250
6120	9650	11830	15270
6140	9670	11870	15330
6170		11890	15350
6190			

Group E Kilocycles	Group F Kilocycles	Group G Kilocycles
17750	21460	25600
17760	21500	25625
17780	21520	25650
17800	21540	25675
17830	21570	25700
	21590	25725
	21610	25750
	21630	25775
	21650	25800
		25825
		25850

(b) Additional frequencies allocated by international agreement may be assigned to international broadcast stations subject to the conditions that no objectional interference results to the service of foreign international broadcast stations which, in the opinion of the Commission, have priority of assignment.

(c) Any frequency licensed to an international broadcast station shall also be available for assignment to other international broadcast stations, provided no objectionable interference is caused to the service of any United States international broadcast station.

(d) An international broadcast station will not be authorized to use more than one frequency listed in any group listed in paragraph (a) without a showing of technical necessity.

(e) Not more than one frequency shall be used simultaneously under the same authorization and call letter designation.

Power requirement. - No international broadcast station will be authorized to install equipment or licensed for operation with a power less than 50 kilowatts.

Supplemental report with renewal application. - A supplemental report shall be filed with and made a part of each application for renewal of license and shall include statements of the following:

(a) The number of hours operated on each frequency.
(b) A list of programs transmitted of special international interest.
(c) Outline of reports of reception and interference and conclusions with regard to propagation characteristics of the frequency assigned.

Frequency control. - The transmitter of each international broadcast station shall be equipped with automatic frequency control apparatus so designed and constructed that it is capable of maintaining the operating frequency within plus or minus 0.005 percent of the assigned frequency.

FACSIMILE BROADCAST STATIONS

Defined. - The term "facsimile broadcast station" means a station licensed to transmit images of still objects for record reception by the general public.

Licensing requirements. - A license for a facsimile broadcast station will be issued only after a satisfactory showing has been made in regard to the following among others:

(a) That the applicant has a program of research and experimentation which indicates reasonable promise of substantial contribution to the development of the facsimile broadcast service.

(b) That sufficient facsimile recorders will be distributed to accomplish the experimental program proposed.

(c) That the program of research and experimentation will be conducted by qualified engineers.

(d) That the applicant is legally and financially qualified and possesses adequate technical facilities to carry forward the program.

(e) That the public interest, convenience, and/or necessity will be served through the operation of the proposed station.

Charges prohibited; restrictions. - (a) A licensee of a facsimile broadcast station shall not make any charge, directly or indirectly, for the transmission of programs.

(b) No licensee of any standard broadcast station or network shall make any additional charge, directly or indirectly, for the transmission of some phase of the programs by a facsimile broadcast station, nor shall commercial accounts be solicited by any licensee of a standard broadcast station or network, or others acting in their behalf, upon representation that images concerning that commercial program will be transmitted by a facsimile station.

Frequency assignment. - (a) The following groups of frequencies are allocated for assignment to facsimile broadcast stations which will be licensed experimentally only:

Group A	Group B	Group C
Kilocycles	Kilocycles	Any frequency above 300,000 kc. excluding band 400,000 to 401,000
25025	43540	
25050	43580	
25075	43620	
25100	43660	
25125	43700	
25150	43740	
25175	43780	
25200	43820	
25225	43860	
25250	43900	
	43940	

(b) Other broadcast or experimental frequencies may be assigned for the operation of facsimile broadcast stations on an experimental basis provided a sufficient need therefor is shown and no interference will be caused to established radio stations.

(c) One frequency only will be assigned to a facsimile station from the groups in paragraph (a) of this section. More than one frequency may be assigned under provisions of paragraph (b) of this section if a need therefor is shown.

(d) Each applicant shall specify the maximum modulating frequencies to be employed.

(e) The operating frequency of a facsimile broadcast station shall be maintanned in accordance with the frequency tolerance given in a previous section: Provided, however, where a lesser tolerance is necessary to prevent interference, the Commission will specify the tolerance.

(f) A facsimile broadcast station authorized to operate on frequencies regularly allocated to other stations or services shall be required to abide by all rules governing the stations regularly operating thereon, which are applicable to facsimile broadcast stations and are not in conflict with previous sections including these rules.

Power. - The operating power of a facsimile broadcast station shall not be in excess of that necessary to carry forward the program of research: Provided, however, Not more than 1,000 watts will be authorized on a frequency in group A. The operating power may be maintained at the maximum rating or less, as the conditions of operation may require.

Supplemental report with renewal application. - A supplemental report shall be filed with and made a part of each application for renewal of license and shall include statements of the following:.

(a) Number of hours operated for transmission of facsimile programs.
(b) Comprehensive report of research and experimentations conducted.
(c) Conclusions and program for further developments of the facsimile broadcast service.
(d) All developments and major changes in equipment.
(e) Amy other pertinent developments.

NONCOMMERCIAL EDUCATIONAL BROADCAST STATIONS

Defined. - The term "noncommercial educational broadcast station" means a station licensed to an organized nonprofit educational agency for the advancement of its education work and for the transmission of educational and entertainment programs to the general public.

Operation and service. - The operation of, and the service furnished by, noncommercial educational broadcast stations shall be governed by the following regulations:

(a) A noncommercial educational broadcast station will be licensed only to an organized nonprofit educational agency and upon a showing that the station will be used for the advancement of the agency's educational program particularly with regard to use in an educational system consisting of several units.

(b) Each station may transmit programs directed to specific schools in the system for use in connection with the regular courses as well as routine and administrative material pertaining to the school system and may transmit educational and entertainment programs to the general public.

(c) Each station shall furnish nonprofit and noncommercial broadcast service. No sponsored or commercial program shall be transmitted nor shall commercial announcements of any character be made. A station shall not transmit the programs of other classes of broadcast stations unless all commercial announcements and commercial references in the continuity are eliminated.

Power. - The pperating power of noncommercial educational broadcast stations shall be not less than 100 watts or greater than 1000 watts unless a definite need for greater power is shown.

Frequency control. - The transmitter of each noncommercial educational broadcast station shall be equipped with automatic frequency control apparatus so designed and constructed that it is capable of maintaining the operating frequency within plus or minus 0.01 percent of the assigned frequency.

Operating schedule. _ Noncommercial educational broadcast stations are not required to operate on any definite schedule or minimum hours.

Equipment requirements. - The transmitting equipment, installation, and operation as well as the location of the transmitter shall be in conformity with the requiremtnts of good engineering practice as released from time to time by the Commission.

Frequencies.. - (a) The following frequencies are allocated for assignment to noncommercial educational broadcast staions : Kilocycles - 42100, 42300, 42500, 42700, and 42900.

(b) Stations serving the same area will not be assigned adjacent frequencies.

(c) Frequency modulation shall be employed exclusively unless it is shown that there is a special need for the use of amplitude modulation.

(d) Only one frequency will be assigned to a station.

DEVELOPMENTAL BROADCAST STATIONS

Defined. - The term "developmental broadcast station" means a station licensed to carry on development and research for the advancement of broadcast services along lines other than those prescribed by other broadcast rules or a combination of closely related developments that can be better carried on under one license.

Licensing requirements; necessary showing. - (a) Licenses for developmental broadcast stations will be issued only after a satisfactory showing has been made in regard to the following, among others:

(1) That the applicant has a program of research and development which cannot be successfully carried on under any of the classes of broadcast stations already allocated, or is distinctive from those classes, or combination of closely related developments that involve different phases of broadcasting which can be pursued better under one license.

(2) That the program of research has reasonable promise of substantial contribution to the development of broadcasting, or is along lines not already thoroughly investigated.

(3) That the program of research and experimentation will be conducted by qualified persons.

(4) That the applicant is legally and financially qualified and possesses adequate technical facilities to carry forward the program.

(5) That the public interest, convenience, and necessity will be served through the operation of the proposed station.

(b) A separate developmental broadcast station license will be issued for each major development proposed to be carried forward. When it is desired to carry on several independent developments, it will be necessary to make satisfactory showing and obtain a license for each.

Program service; charges prohibited; announcements. - (a) A license of developmental broadcast stations shall broadcast programs when they are necessary to the experiments being conducted. No regular program service shall be broadcast unless specifically authorized by the license.

(b) A licensee of a developmental broadcast station shall not make any charge, directly or indirectly, for the transmission of programs, but may transmit the programs of a standard broadcast station or network including commercial programs, if the call letter designation when identifying the developmental broadcast station is given on its assigned frequency only and the statement is made over the developmental broadcast station that the program of a broadcast station or network (identify by call letters or name of network) is being broadcast in connection with the developmental work. In case of the rebroadcast of the program of any broadcast station, section 4.10 applies.

Frequency assignment. - (a) The following frequencies are allotted for assignment to developmental broadcast stations.

	1614	12855, 12870	12862.5	116050
2396, 2400	2398	17300, 17320	17310	116250
3490, 3495	3492.5	23100		116450
4795, 4800	4797.5	30660		116580
6420, 6430	6425	31020		117050
9130, 9140	9135	31140		117250
		31180		117650
		31540		118050
		33340		118250
		33460		118450
		33620		118650
		35060		118850
		35460		156525
		37060		156975
		37140		157425
		37540		157725
		39140		158175
		39460		159075
		39540		160425
				161325
				161775
				162000 to 168000
				210000 to 216000
				264000 to 270000
				300000 to 400000
				401000 and above

(b) A license will be issued for more than one of these frequencies upon a satisfactory showing that there is need therefor.

(c) The frequencies suited to the purpose and in which there appears to be the least or no interference to established stations shall be selected.

(d) In cases of important experimentation which cannot be conducted successfully on the frequencies allocated in paragraph (a) of this section, the Commission may authorize developmental broadcast stations to operate on any frequency allocated for broadcast stations or any frequencies allocated for other services under the jurisdiction of the Commission upon satisfactory showing that such frequencies can be used without causing interference to established services.

Frequency tolerance. -(a) The operating frequency of a developmental broadcast station shall be maintained in accordance with the frequency tolerance given in section 4.1: Provided, however Where lesser tolerance is necessary to prevent interference, the Commission will specify the tolerance.

(b) The operating power of a developmental broadcast station shall not be in excess of that necessary to carry on the program of research. The operating power may be maintained at the maximum rating or less, as the conditions of operation may require.

Supplemental report with renewal application. - A supplemental report shall be filed with and made a part of each application for renewal of license and shall include statements of the following, among others:

(a) The number of hours operated.
(b) Comprehensive report on research and experiments conducted.
(c) Conclusions and program for further development of the broadcast service.
(d) All developments and major changes in equipment.
(e) Any other pertinent developments.

Frequency restrictions. - A developmental broadcast station authorized to operate on frequencies regulary allocated to other stations or services, shall be required to abide by all rules governing the stations operating regularly thereon which are applicable to developmental broadcast stations and are not in conflict with sections including these rules.

CHAPTER XIII

CURRENT FCC FREQUENCY ALLOCATIONS

Frequency in mc	United States Allocations
Up to 0.1	Fixed
0.1-0.16	Coastal, marine relay, ship, mobile press, fixed, Alaskan
0.16-0.2	Fixed
0.2-0.28	Air navigation aids
0.28-0.32	Maritime beacons
0.32-0.415	Air navigation aids
0.415-0.49	Coastal, marine relay, ship
0.49-0.51	Mobile, distress & calling frequency 0.5 mc (500 kc)
0.51-0.535	Mobile (telegraphy)
0.535-1.605	Broadcasting (non-gov)
1.605-1.8	Police, aviation, relay broadcast, special Alaskan, disaster communication including amateur disaster networks
1.8-2	Navigation aids
2-2.05	Government
2.05-2.065	Ship telegraph
2.065-2.075	Mobile (distress and calling frequency 2.07 mc)
2.075-2.1	Ship telegraph
2.1-2.25	Ship telephone, relay broadcast
2.25-2.3	Police point-to-point, ship telephone, aviation, special, relay broadcast
2.3-2.35	Coastal telegraph, marine relay
2.35-2.495	Police, ship telephone, Alaskan
2.495-2.505	Government
2.505-2.7	Coastal harbor telephone, Alaskan
2.7-2.85	Fixed, maritime mobile telephone, police point-to-point, special emergency, relay broadcast Alaskan
2.85-3.125	Aeronautical mobile
3.125-3.2	Aeronautical fixed
3.2-3.33	Government
3.33-3.45	Forestry
3.45-3.5	Government
3.5-4	Amateur
4-4.1	Fixed, except aeronautical fixed
4.1-4.135	Coastal, marine relay, ship
4.135-4.145	Mobile (distress and calling frequency 4.14 mc)
4.145-4.5	Coastal, marine relay, ship, mobile press
4.5-4.89	Fixed, aero. fixed, coastal telephone, Alaskan
4.89-5.01	Government
5.01-5.3	Fixed, aero. fixed
5.3-5.5	Fixed, aero. fixed, Alaskan
5.5-5.8	Aeronautical mobile
5.86-6	Fixed, aero. fixed
6-6.2	International broadcast
6.2-6.3	Coastal, marine relay, ship
6.3-6.45	Fixed, aero. fixed
6.45-6.6	Aeronautical mobile
6.6-6.9	Fixed, aero. fixed
6.9-7	Government

Frequency in mc	United States Allocations
7-7.3	Amateur
7.3-8.2	Fixed, aero. fixed, Alaskan
8.2-8.275	Coastal, marine relay, ship
8.275-8.285	Mobile (distress and calling freq. 8.28mc)
8.285-8.7	Coastal, marine relay, ship, mobile press
8.7-8.9	Aeronautical mobile
8.9-9	Fixed, aero. fixed, coastal telephone
9-9.5	Fixed, aero. fixed
9.5-9.7	International broadcast
9.7-9.99	Fixed, aero, fixed
9.99-10.2	Government (standard freq. 10mc.)
10.2-11.3	Fixed, aero. fixed
11.3-11.5	Aeronautical mobile
11.5-11.7	Fixed, aero. fixed
11.7-11.9	International broadcast
11.9-12.3	Fixed, aero. fixed
12.3-12.415	Coastal, marine relay, ship
12.415-12.425	Mobile (calling freq. 12.42mc)
12.425-12.95	Coastal, marine relay, ship, mobile press
12.95-13.05	Government
13.05-13.25	Fixed, aero. fixed
13.25-13.35	Fixed, aero. fixed, coastal telephone
13.35-13.6525	Fixed, aero. fixed
13.6525-13.6675	Industrial, scientific, and medical tuned to 13.66 mc
13.6675-14	Fixed, aero. fixed
14-14.4	Amateur
14.4-14.985	Fixed, aero. fixed
14.985-15.1q	Government
15.1-15.3	International broadcast
15.3-16.4	Fixed, aero. fixed
16.4-16.555	Coastal, amrine relay, ship, mobile press, aeronautical
16.555-16.565	Mobile (calling freq. 16.56)
16.565-17.1	Coastal, marine relay, ship, mobile press, aero.
17.1-17.6	Fixed, Aero. fixed
17.6-17.7	Fixed, aero. fixed, coastal telephone
17.7-17.9	International broadcast
17.9-19.985	Fixed, aero. fixed
19.985-20.015	Government (standard freq. 25 mc)
25.015-27.185	Gov. and non.-gov. fixed and mobile
27.185-27.455	Scientific, industrial and medical, centered on 27.32 mc
27.455-28	Gov. and non-gov. fixed and mlbile
28-29.7	Amateur
29.7-30	Gov. and non-gov. fixed and mobile
30-30.5	Government
30.5-32	Non-gov. fixed and mobile
32-33	Government
33-34	Non-government, fixed and mobile
34-35	Government
35-36	Non-gov., fixed and mobile
36-37	Government

Frequency in mc	United States Allocations
37-38	Non-gov. fixed and mobile
38-39	Government
39-40	Non-gov. fixed and mobile
40-40.96	Government
40.96-41	Scientific, industrial and medical
41-42	Government
42-44	Non-gov. fixed and mobile
44-50	Television channel No.1
50-54	Amateur
54-60	Television channel No.2
60-66	Television channel No.3
66-72	Television channel No.4
72-76	Non-gov. fixed and mobile
76-82	Television channel No.5
82-88	Television channel No.6
88-92	Non-commercial educational f-m
92-106	Frequency-modulation broadcasting
106-108	Facsimile
108118	Government
118-122	Airport control
122-132	Aero, mobile (primarily non-gov.)
132-144	Government
144-148	Amateur
148-152	Government
152-162	Non-gov. fixed and mobile
162-174	Government
174-186	Television and government
186-216	Television fixed and mobile
216-220	Government
220-225	Amateur after Jan. 1, 1949; interim allocations are 216-231 Radar distance indicators (British); 231-236 Government (within interference range of above); 235-240 Amateur
225-328.6	Military and civil aviation channels
328.6-335.4	Glide path air naviagational aids
335.4-400	Military and civil aviation channels
400-420	Government, including radiosonde
420-450	Amateur and air navigation
450-460	Non-gov. fixed and mobile
460-470	Citizen's radio
470-480	Facsimile broadcasting
480-920	Television
920-940	Experimental broadcast services
940-960	Fixed and experimental broadcasting
960-1215	Navigation aids
1215-1295	Amateur
1295-1375	Non-gov- (television relay)
1375-1425	Non-government
1425-1600	Government
1600-1700	Air navigation aids

Frequency in mc	United States Allocations
1700-1750	Meteorological
1750-2100	Non-gov. fixed and mobile
2100-2300	Government
2300-2450	Amateur
2450-2700	Non-gov. fixed and mobile
2700-2900	Meterorologizal and air navigation aids
2900-3700	Navigation aids
3700-4000	Non-government
4000-4200	Air navigation aids (altimeters)
4200-4400	Non-government
4400-5000	Government
5000-5250	Instrument landing air naviaation aids
5250-5650	Amateur
5650-7050	Non-gov. fixed and mobile
7050-8500	Government
8500-9300	Government
9300-9600	Naviagation aids
9600-10000	Government
10000-10500	Amateur
10500-13000	Non-gov. fixed and mobile
13000-16000	Government
16000-18000	Non-gov. fixed and mobile
18000-21000	Government
21000-22000	Amateur
22000-26000	Government
26000-30000	Non-gov. fixed and mobile
30000 - up	Experimental

CHAPTER XIV

PREFACE

The full weight of American engineering productivity and ingenuity has, within the past few years, been turned to the problem of evolving workable and economical television and F-M systems for the American public. That progress has been made is substantiated by the tremendous expansion program which is currently under way both by the receiver manufacturers and the broadcast companies.

One of the most fundamental considerations in radio and television engineering is the establishment of a set of flexible rules or standards which serve as a guide for the engineer. Within the framework of these standards the engineer then sets about to develop a receiver or an instrument, or whatever else is desired, so that it best fits its intended purpose. For the television and F-M engineer, such a set of rules are those which have been established by the F. C. C. and which are given in the following pages. Since television and F-M are, and undoubtedly will continue to be, subject to change as new and improved methods are evolved, so will there be changes in the regulations. However, for the moment, these represent the latest rules promulgated by the F. C. C.

American Television Inc.

FEDERAL COMMUNICATIONS COMMISSION
Washington 25, D.C.

STANDARDS OF GOOD ENGINEERING PRACTICE CONCERNING TELEVISION BROADCAST STATIONS

Introduction

There are presented herein the Commission's engineering standards relating to the allocation and operation of Television broadcast stations. The Commission's Rules and Regulations contain references to these standards, which have been approved by the Commission and thus are considered as reflecting its opinion in all matters involved.

The standards set forth herein are those deemed necessary for the construction and operation of Television broadcast stations to meet the requirements of technical regulations and for operation in the public interest along technical lines not otherwise enunciated. These standards are based upon the best engineering data available, including evidence at hearings, conferences with radio engineers, and data supplied by manufacturers of radio equipment and by licensees of Television broadcast stations. These standards are complete in themselves and supersede previous engineering standards or policies of the Commission concerning Television broadcast stations. While these standards provide for flexibility and indicate the conditions under which they are applicable, it is not expected that material deviation from the fundamental principles will be recognized unless full information is submitted as to the need and reasons therefor.

These standards will necessarily be revised from time to time as progress is made in the art. The Commission will accumulate and analyze engineering data available as to the progress of the art so that these standards may be kept current with technical developments.

TABLE OF CONTENTS

1. Definitions.

A. General

1. Television Broadcast station. --The term "television broadcast station" means a station in the television broadcast band transmitting simultaneous visual and aural signals intended to be received by the general public.

2. Television broadcast band. --The term "television broadcast band" means those frequencies in the band extending from 44 to 216 megacycles which are assignable to television broadcast stations. These frequencies are 44 to 50 megacycles (Channel No. 1), 54 to 72 megacycles (Channels 2 through 4), 76 to 88 megacycles (Channels 5 and 6), and 174 to 216 megacycles (Channels 7 through 13).

3. Television channel. --The term "television channel" means a band of frequencies 6 megacycles wide in the television broadcast band and designated either by number or by the extreme lower and upper frequencies.

4. Television transmission standards. --The term "television transmission standards" means the standards which determine the characteristics of the television signal as radiated by a television broadcast station. (See Section 2 A).

5. Standard television signal. --The term "standard television signal" means a signal which conforms with the television transmission standards.

6. Television transmitter. --The term "television transmitter" means the radio transmitter or transmitters for the transmission of both visual and aural signals.

7. Antenna field gain. --The term "antenna field gain" of a television antenna means the ratio of the effective free space field intensity produced at one mile in the horizontal plane expressed in millivolts per meter for 1 kilowatt antenna input power to 137.6 mv/m.

8. Free space field intensity. --The term "free space field intensity" means the field intensity that would exist at a point in the absence of waves reflected from the earth or other reflecting objects.

9. Polarization. --The term "polarization" means the direction of the electric vector as radiated from the transmitting antenna.

10. Effective radiated power. --The term "effective radiated power" means the product of the antenna power (transmitter output power less transmission line loss) times (1) the antenna power gain, or (2) the antenna field gain squared.

11. Service area. --The term "service area" as applied to television broadcasting means the service resulting from an assigned effective radiated power and antenna height above average terrain.

12. Antenna height above average terrain. --The term "antenna height above average terrain" means the average of the antenna heights above the terrain from two to ten miles from the antenna. (In general a different antenna height will be determined by each direction from the antenna. The average of these various heights is considered as the antenna height above average terrain.

B. Visual transmitter

1. Visual transmitter. --The term "visual transmitter" means the radio equipment for the transmission of the visual signal only.

2. Amplitude modulation. --The term "amplitude modulation" (AM) means a system of modulation in which the envelope of the transmitted wave contains a component similar to the wave form of the signal to be transmitted.

3. Aspect ratio. --The term "aspect ratio" means the numerical ratio of the frame width to frame height, as transmitted.

4. Black level. --The term "black level" means the amplitude of the modulating signal corresponding to the scanning of a black area in the transmitted picture.

5. Color transmission. --The term "color transmission" means the transmission of television signals which can be reproduced with different color values.

6. Field frequency. --The term "field frequency" means the number of times per second the frame area is fractionally scanned in the interlaced scanning.

7. Frame. --The term "frame" means one complete picture.

8. Frame frequency. --The term "frame frequency" means the number of times per second the picture area is completely scanned.

9. Interlaced scanning. --The term "interlaced scanning" means a scanning process in which successively scanned lines are spaced in integral number of line widths, and in which the adjacent lines are scanned during successive cycles of the field frequency scanning.

10. Monochrome transmission. --The term "monochrome transmission" means the transmission of television signals which can be reproduced in gradations of a single color only.

11. Negative transmission. --The term "negative transmission" means that a decrease in initial light intensity causes an increase in the transmitted power.

12. Positive transmission. --The term "positive transmission" means that an increase in initial light intensity causes an increase in the transmitted power.

13. Progressive scanning. --The term "progressive scanning" means a scanning process in which scanning lines trace one dimension substantially parallel to a side of the frame and in which successively traced lines are adjacent.

14. Scanning. --The term "scanning" means the process of analyzing successively, according to a predetermined method, the light values of picture elements constituting the total picture area.

15. Scanning line. -- The term "scanning line" means a single continuous narrow strip containing highlights, shadows, and half-tones which is determined by the process of scanning.

16. Synchronization. --The term "synchronization" means the maintaining of one operation in step with another.

17. Vestigial side band transmission. --The term "vistigial side band transmission" means a system of transmission wherein one of the generated side bands is partially attenuated at the transmitter and radiated only in part. (See Appendix II).

18. Visual frequency. --The term "visual frequency" means the frequency of the signal resulting from television scanning.

19. Visual transmitter power. --The term "visual transmitter power" means the peak power output when transmitting a standard television signal .

20. Peak power. --The term "peak power" means the power over a radio frequency cycle corresponding in amplitude to synchronizing peaks.

C. Aural Transmitter.

1. Aural transmitter. --The term "aural transmitter" means the radio equipment for the transmission of the aural signal only.

2. Center frequency. --The term "center frequency" means:
(1) The average frequency of the emitted wave when modulated by a sinusoidal signal.
(2) The frequency of the emitted wave without modulation.

3. Frequency modulation. --The term "frequency modulation" means a system of modulation where the instantenous radio frequency varies in proportion to the instantaneous amplitude of the modulating signal (amplitude of modulating signal to be measured after pre-emphasis, if used) and the instantaneous radio frequency is independent of the frequency of the modulating signal.

4. Frequency swing. --The term "frequency swing" means the instantaneous departure of the frequency of the emitted wave from the center frequency resulting from modulation.

5. Percentage modulation. --The term "percentage modulation" as applied to frequency modulation means the ratio of the actual frequency swing to the frequency swing defined as 100 percent modulation, expressed in percentage. For the aural transmitter of television broadcast stations, a frequency swing of $\pm$ 25 kilocycles is defined as 100 percent modulation.

2. Transmission Standards and Changes or Modifications Thereof.

A. Transmission Standards

1. The width of the television broadcast channel shall be six megacycles per second.

2. The visual carrier shall be located 4.5 megacycles lower in frequency than the aural center frequency.

3. The aural center frequency shall be located 0.25 megacycles lower than the upper frequency limit of the channel.

4. The visual transmission amplitude characteristic shall be as shown in Appendix II.

5. The number of scanning lines per frame period shall be 525, interlaced two to one.

6. The frame frequency shall be 30 per second and the field frequency shall be 60 per second.

7. The aspect ratio of the transmitted television picture shall be 4 units horizontally to 3 units vertically.

8. During active scanning intervals, the scene shall be scanned from left to right horizontally and from top to bottom vertically, at uniform velocities.

9.* A carrier shall be modulated within a single television channel for both picture and synchronizing signals, the two signals comprising different modulation ranges in amplitude (See appendices I and II).

10. A decrease in initial light intensity shall cause an increase in radiated power (negative transmission).

11. The black level shall be represented by a definite carrier level, independent of light and shade in the picture.

12. The pedestal level (normal black level) shall be transmitted at 75 per cent (with a tolerance of plus or minus 2.5 per cent) of the peak carrier amplitude.

13. The maximum white level shall be 15 per cent or less of the peak carrier amplitude.

14. The signals radiated shall have horizontal polarization.

15. A radiated power of the aural transmitter not less than 50% or more than 15% of the peak radiated power of the video transmitter shall be employed.

16.*Variation of Output.--The peak-to-peak variation of transmitter output within one frame of video signal due to all causes, including hum, noise, and low-frequency response, measured at both synchronizing peak and pedestal level, shall not exceed 5% of the average synchronizing peak signal amplitude.

17.*Black Level. --The black level should be made as nearly equal to the pedestal level as the state of the art will permit. If they are made essentially equal, satisfactory operation will result and improved techniques will later lead to the establishment of the tolerance if necessary.

18. *Brightness Characteristics.--The transmitter output shall vary in substantially inverse logarithmic relation to the brightness of the subject. No tolerances are set at this time.

*These items are subject to change but are considered the best practice under the present state of the art. They will not be enforced pending a further determination thereof.

B. Change or Modification of Transmission-standards

The Commission will consider the question whether a proposed change or modification of transmission standards adopted for television would be in the public interest, convenience and necessity, upon petition being filed by the person proposing such change or modification, setting forth the following:

(1) The exact character of the change or modification proposed;

(2) The effect of the proposed change or modification upon all other transmission standards that have been adopted by the Commission for Television broadcast stations;

(3) The experimentation and field tests that have been made to show that the proposed change or modification accomplishes an improvement and is technically feasible;

(4) The effect of the proposed change or modification in the adopted standards upon operation and obsolescence of receivers;

(5) The change in equipment required in existing television broadcast stations for incorporating the proposed change or modification in the adopted standards, and

(6) The facts and reasons upon which the petitioner bases his conclusion that the proposed change or modification would be in the public interest, convenience and necessity.

Should a change or modification in the transmission standards be adopted by the Commission, the effective date thereof will be determined in the light of the considerations mentioned in sub-paragraph (4) above.

3. Engineering Standards of Allocation

A. Sections 3.603 through 3.606 of the Commission's Rules prescribes the basis of assignment of television broadcast facilities. Section 3.601 indicates the groups of channels that are available for assignment to television broadcast stations. As indicated by these rules, the number of channels are limited and therefore have been allocated in advance to specific areas. This listing has been carefully planned with a view of providing the greatest service to a maximum number of people and in general no departure from this plan will be made. However, where it can be shown that the public interest will be benefited by an alteration or rearrangement in this listing, the Commission will consider such adjustments as are necessary.

B. The extent of service is determined by the point at which the ground wave is no longer of sufficient intensity to provide satisfactory broadcast service. The field intensity considered necessary for service is as follows:

TABLE I

Area	Medial Field Intensity
City, business or factory areas	5000 uv/m
Residential and Rural areas	500 uv/m

These figures are based upon the usual noise levels encountered in the two areas and upon the absence of interference from other television broadcast stations. The Commission will require that the transmitting antenna be so located as to provide a coverage area which is contiguous with the population density of the cities or metropolitan area with which the station is associated.

The field intensity indicated above for computing coverage is the visual transmitter operating peak power.

C. The service area is predicted as follows:

Profile graphs must be drawn for at least eight radials from the proposed antenna site. These profiles should be prepared for each radial beginning at the antenna site and extending to ten miles therefrom. Normally the radials are drawn for each 45^{o} of azimuth; however, where feasible the radials should be drawn for angles along which roads tend to follow. (The latter method may be helpful in obtaining topographical data where otherwise unavailable, and is particularly useful in connection with mobile field intensity measurements of the station and the correlation of such measurements with predicted field intensities). In each case one or more radials must include the principal city or cities to be served, particularly in cases of rugged terrain, even though the city may be more than 10 miles from the antenna site. The profile graph for each radial should be plotted by contour intervals of from 40 to 100 feet and, where the data permits, at least 50 points of elevation (generally uniformly spaced) should be used for each radial. In instances of very rugged terrain where the use of contour intervals of 100 feet would result in several points in a short distance, 200 or 400 foot contour intervals may be used for such distances. On the other hand, where the terrain is uniform or gently sloping the smallest contour interval indicated on the topographic map (see below) should be used, although only a relatively few points may be available. The profile graph should accurately indicate the topography for each radial, and the graphs should be plotted with the distance in miles as the abscissa and the elevation in feet above mean sea level as the ordinate. The profile graphs should indicate the source of the topographical data employed. The graph should also show the elevation of the center of the radiating system. The graph may be plotted either on rectangular coordinate paper or on special paper which shows the curvature of the earth. It is not necessary to take the curvature of the earth into consideration in this procedure, as this factor is taken care of in the charts showing signal intensities. (Appendix IV) The average elevation of the eight mile distance between two and ten miles from the antenna site should then be determined from the profile graph for each radial. This may be obtained by averaging a large number of equally spaced points, by using a planimeter, or by obtaining the median elevation (that exceeded for 50% of the distance) in sectors and averaging those values.

To determine the distance to a particular contour concerning the range of television broadcast stations, Appendix IV should be used. These charts have been prepared for frequencies in the center of the various portions of the television band and are to be used as follows: Figure 1 for Channel 1; Figure 2 for Channels 2 through 4; Figure 3 for Channels 5 and 6; and Figure 4 for Channels 7 through 13. The distance to a contour is determined by the effective radiated power and the antenna height. The height of the antenna used in connection with Appendix IV should be the height of the center of the proposed antenna radiator above the average elevation obtained by the proceding method. The distances shown by Appendix IV are based upon an effective radiated power of one kilowatt; to use the charts for other powers, the sliding scale associated with the charts should be trimmed and used as the ordinate scale. This sliding scale is placed on the charts with the appropriate gradation for power in line with the lower line of the top edge of the charts. The right edge of the scale is placed in line with the appropriate antenna height graduations and the charts then become direct reading for this power and antenna height. Where the antenna height is not one of those for which a scale is provided, the signal strength or distance is determined by interpolation between the curves connecting the equidistant points.

The foregoing process of determing the extent of the required contours shall be followed in determining the boundary of the proposed service area. The areas within the 5000 uv/m and 500 uv/m contours must be determined and submitted with each application for television broadcast stations. Each application shall include a map showing these contours, and for this purpose Sectional Aeronautical charts or other maps having a convenient scale may be used. The map shall show the radials along which the profile charts and expected field strength have been determined. The area within each contour should then be measured (by planimeter or other approximate means) to determine the number of square miles therein. In computing the area within the contours, exclude (1) areas beyond the borders of the United States, and (2) large bodies of water, such as ocean areas, gulfs, sounds, bays, large lakes, etc., but not rivers. Where interference is involved such areas shall be determined as indicated by Section V.

In cases where the terrain in one or more directions from the antenna site departs widely from the average elevation of the two to ten mile sector, the application of this prediction method may indicate contour distances that are different from these which may be made if desired concerning the distance to the contour as determined by other means. Such showing should include data concerning the procedure employed and sample calculations. For example, a mountain ridge may indicate the practical limit of service although the prediction method may indicate the contour elsewhere. In cases of such limitations, the map of predicted coverage should show both the regular predicted area and the area as limited or extended by terrain. Both areas should be measured, as previously described; the area obtained by the regular prediction method should be given in the application form, with a supplementary note giving the limited or extended area. In special cases the Commission may require additional information as to the terrain in the proposed service area.

In determining the population served by television broadcast stations, it is considered that the built-up city areas and business districts in cities having over 10,000 population and located beyond the 5000 uv/m contour do not receive adequate service. Minor Civil Division maps (1940 Census) should be used in making population counts, excluding cities not receiving adequate service. Where a contour divides a minor division, uniform distribution of population within the division should be assumed in order to determine the population included within the contour, unless a more accurate count is available.

4. Topographical Data

In the preparation of the profile graphs previously described, the elevations or contour intervals shall be taken from the U.S. Geological Topographical Quadrangle Sheets for all areas for which such maps are available. If such maps are not published for the area in question, the next best topographic information should be used. Topographic data may sometimes be obtained from state and municipal agencies. The data from the Sectional Aeronautical Charts (including bench marks), or railroad depot elevations and highway elevations from road maps, may be used where no better information is available. In cases where limited topographic data can be obtained, use may be made of an altimeter in a car driven along roads extending generally radially from the transmitter site.

The Commission will not ordinarily require the submission of topographical maps for areas beyond 15 miles from the antenna site, but the maps must include the principal city or cities to be served. If it appears necessary, additional data may be requested.

The U.S. Geological Survey Topography Quadrangle Sheets may be obtained from the U.S. Geological Survey, Department of the Interior, Washington, D.C., for ten cents each. The Sectional Aeronautical Charts are available from the U.S. Coast and Geodetic Survey, Department of Commerce, Washington, D.C., for twenty-five cents each. Other sources of topographic maps or data will be furnished at a later date.

5. Interference Standards

Field intensity measurements are preferable in predicting interference between Television broadcast stations and should be used, when available, in determing the extent of interference. (For methods and procedure, see Section 6). In lieu of measurements, the interference should be predicted in accordance with the method described herein.

Objectionable visual interference is considered to exist when the interfering signal exceeds that given by the ratios of Table II. In Table II the desired signal is median field and the undesired signal is the tropospheric signal intensity exceeded for 10% of the time.

TABLE II

Channel Separation	Ratio of Desired to Undesired Signals
Same channel	100:1
Adjacent channel	2:1

It is considered that stations on alternate channels or on channels separated by 4 Mc can be operated in the same city or area without objectionable interference, (i.e., on this basis, channels 1 and 2 or 4 and 5 could be used in the same city or area).

As an example of the application of the data contained in Table II, objectionable interference from a co-channel station is considered to exist at the 500 uv/m contour of a station if a tropospheric signal from the co-channel station equals or exceeds 5 uv/m for at least ten per cent of the time. The ten per cent values for one kilowatt of power and various antenna heights are given in Appendix V*, and values for other powers may be obtained by using the sliding scale as for Appendix IV. The values indicated by Appendix V are based upon available data, and are subject to change as additional information concerning tropospheric wave propagation is obtained.

At the present time it is considered sufficient to consider only the ground wave field intensities in determining the extent of adjacent channel interference.

In determining the points at which the interference ratio is equal to the values shown in Table II, the field intensities for the two interfering signals under consideration should

*Charts for Appendix V will be available at some future date when sufficient measurements of tropospheric signals are available. Until such time as these charts are available, interference should be predicted on the basis of ground wave charts (Appendix IV).

be computed for a considerable number of points along the line between the two stations. Using this data, field intensity versus distance curves should be plotted (e.g., cross-curves on graph paper) in order to determine the points on this path where the interference ratios exist. The points established by this method, together with the points along the contours where the same ratios are determined, are considered to be generally sufficient to predict the area of interference. Additional points may be required in case of irregular terrain or directional antenna systems.

The area of interference, if any, shall be shown in connection with the map of predicted coverage required by the application form, together with the basic data employed in computing such interference. The map shall show the interference, within the 500 uv/m contour.

6. Field Intensity Measurements in Allocation.

When field intensity measurements are required by the Commission's rules or when employed in determining the extent of service or interference of existing stations, such measurements should be made in accordance with the procedure outlined herein.

Measurements made to determine the service and interference areas of television broadcast stations should be made with mobile equipment along roads which are as close and similar as possible to the radials showing topograph which were submitted with the application for construction permit. Suitable measuring equipment and a continuous recording device must be employed, the chart of which is either directly driven from the speedometer of the automobile in which the equipment is mounted or so arranged that distance and identifying landmarks may be readily noted. The measuring equipment must be calibrated against recognized standards of field intensity and so constructed that it will maintain an acceptable accuracy of measurement while motion or when stationary. The equipment should be so operated that the recorder chart can be calibrated directly in field intensity in order to facilitate analysis of the chart. The receiving antenna must be non-directional and horizontally polarized.

Mobile measurements should be made with a minimum chart speed of 3 inches per mile and preferably 5 or 6 inches per mile. Locations shall be noted on the recorder chart as frequently as necessary to definitely fix the relation between the measured field intensity and the location. The time constant of the equipment should be such as to permit adequate analysis of the charts, and the time constant employed shall be shown. Measurements should be made to a point on each radial well beyond the particular contour under investigation.

While making field intensity measurements the visual transmitter shall be used. It is recommended that a black picture be transmitted and operated at black level without synchronization peaks. Operation at a power somewhat less than black level is permissible but too great a reduction in power is not recommeded due to the difficulty of recording weak signals. In any event, an appropriate factor shall be used to convert the readings obtained to the field strength that would exist on synchronization peaks while operating at the authorized power. If other means of measurements are to be used a request should be made to the Commission stating the reasons therefore and the means to be used.

After the measurements are completed, the recorder chart shall be divided into not less than 15 sections on each equivalent radial from the station. The field intensity in each section of the chart shall be analyzed to determine the field intensity received 50 per cent of the distance (median field) throughout the section, and this median field intensity associated with the corresponding sector of the radial. The field intensity figures must be corrected for a receiving antenna elevation of thirty feet and for any directional effects of the automobile not otherwise compensated. This data should be plotted for each radial, using a log-log coordinate paper with distance as the abscissa and field intensity as the ordinate. A smooth curve should be drawn through these points (of median fields for all sectors and this curve used to determine the distance to the desired contour. The distances obtained for each radial may then be plotted on the map of predicted coverage or on polar coordinate paper (excluding water areas, etc.) to determine the service and interference areas of a station.

In making measurements to establish the field intensity contours of a station mobile recordings should be made along each of the radials drawn in Section 3C above. Measurements should extend from the vicinity of the station out to the 500 uv/m measured contour and somewhat beyond. These measurements would be made for the purpose of determining the variation of the measured contours from those predicted. Adjustment of power or antenna may be required to fit the actual contours to that predicted.

In predicting tropospheric interference on the basis of the above measurements, such measurements shall be carried out in the manner indicated above to determine the 500 uv/m contour. Using the appropriate figure in Appendix IV for the channel involved and the sliding scale, the equivalent radiated power shall be determined by placing the sliding scale on the chart (using the appropriate antenna height) and moving the scale until the distance to the 500 uv/m contours (as determined above), and the 500 uv/m mark are opposite. The equivalent radiated power is then read from the sliding scale where it crosses the lower line of the top edge of the chart. Changing to the corresponding figure in Appendix V and using the equivalent radiated power just determined, the distance to the interfering contour under investigation is read in the usual manner.

In certain cases the Commission may desire more information or recordings and in those instances special instructions will be issued. This may include fixed location measurements to determine tropospheric propagation and fading ratios.

Complete data taken in conjunction with field intensity measurements shall be submitted to the Commission in affidavit form, including the following:

A. Map or maps showing the roads or points where measurements were made, the service and/or interference areas determined by the prediction method and by the measurements, and any unusual terrain characteristics existing in these areas. (This map may preferably be of a type showing topography in the area). The 5000 and 500 uv/m contours shall be shown.

B. If a directional transmitting antenna is employed, a diagram on polar coordinate paper showing the predicted free space field intensity in millivolts per meter at one mile in all directions. (See Section 8).

C. A full description of the procedures and methods employed including the type of equipment, the method of installation and operation, and calibration procedures.

D. Complete data obtained during the survey, including calibration.

E. Antenna system and power employed during the survey.

F. Name, address, and qualifications of the engineer or engineers making the measurements.

All data shall be submitted to the Commission in triplicate, except that only the original or one photostatic copy need be submitted of the actual recording tapes.

7. Transmitter Location

A. The transmitter location should be as near the center of the proposed service area as possible consistent with the applicant's ability to find a site with sufficient elevation to provide service throughout the area. Location of the antenna at a point of high elevation is necessary to reduce to a minimum the shadow effect on propagation due to hills and buildings which may reduce materially the intensity of the station's signals in a particular direction. The transmitting site should be selected consistent with the purpose of the station, i.e., whether it is intended to serve a small city, a metropolitan area or a large area. Inasmuch as service may be provided by signals of 5000 uv/m or greater field intensities in metropolitan areas, and inasmuch as signals below 500 uv/m may provide service in rural areas, considerable latitude in the geographical location of the transmitter is permitted; however, the necessity for a high elevation for the antenna may render this problem difficult. In general, the transmitting antenna of a station should be located at the most central point at the highest elevation available. In providing the best degree of service to an area, it is usually preferable to use a high antenna rather than a lower antenna with increased transmitter power. The location should be so chosen that line-of-sight can be obtained from the antenna over the principal city or cities to be served. In no event should there be a major obstruction in this path.

B. The transmitting location should be selected so the the 5000 uv/m contour encompasses the urban population within the area to be served and the 500 uv/m or the interference free contour coincides generally with the limits of the area to be served. It is recognized that topography, shape of the desired service area, and population distribution may make the choice of a transmitter location difficult. In such cases consideration may be given to the use of a directional antenna system, although it is generally preferable to choose a site where a non-directional antenna may be employed.

C. In cases of questionable antenna locations it is desirable to conduct propagation tests to indicate the field intensity expected in the principal city or cities to be served and in other areas, particularly where severe shadow problems may be expected. In considering applications proposing the use of such locations, the Commission may require site tests to be made. Such tests should be made in accordance with the measurements procedure previously described, and full data thereon must be supplied to the Commission. Test transmitters should employ an antenna having a height as close as possible to the proposed antenna height, using a ballon or other support if necessary and feasible. Information concerning the authorization of site tests may be obtained from the Commission upon request.

D. Present information is not sufficiently complete to establish "blanket areas" of television broadcast stations. A "blanket area" is that area adjacent to a transmitter in which the reception of other stations is subject to interference due to the strong signal from this station. Where it is found necessary to locate the transmitter in a residential area where blanketing problems may appear to be excessive the application must include a showing concerning the availability of other sites. The authorization of station construction in areas where blanketing problems appear to be excessive will be on the basis that the applicant will assume full responsibility for the adjustment of reasonable complaints arising from excessively strong signals of the applicant's station.

Cognizance must of course be taken regarding the possible hazard of the proposed antenna structure to aviation and the proximity of the proposed site to airports and airways. In passing on proposed construction, the Commission refers each case to the Civil Aeronautics Administration for its recommendations. Antenna painting and/or lighting may be required at the time of construction or at a later date.

8. Antenna Systems

A. An antenna which is high in respect to the average level of the territory it serves is desirable in order to reduce the effect of shadows. The antenna must be constructed so that it is as clear as possible of surrounding building or objects that would cause shadow problems.

B. Applications proposing the use of directional antenna systems must be accompanied by the following:

(1) Complete description of the proposed antenna system.
(2) Orientation of array with respect to true north; time phasing of fields from elements (degrees leading or lagging); space phasing of elements (in feet and degrees); and ratio of fields from elements.
(3) Calculated field intensity pattern (on letter-size polar coordinate paper) giving the free space field intensity in millivolts per meter at one mile in the horizontal plane, together with the formula used, constants employed, sample calculations, and tabulations of calculation data.
(4) Name, address, and qualifications of the engineer making the calculations.

C. Applications proposing (1) the use of television broadcast antennas in the immediate vicinity (i.e., 200 feet or less) of television broadcast antennas operating on a channel within 20% in frequency of the proposed channel, or (2) the use of television antennas on channels 5 or 6 in the immediate vicinity of FM broadcast antennas, must include a showing as to the expected effect if any, of such proximate operation.

D. In cases where it is proposed to use a tower of a standard broadcast station as a supporting structure for a television broadcast antenna, an application for construction permit (or modification of construction permit) for such station must be filed for consideration with the television application. An application may be required for other classes of stations when the tower is to be used in connection with a television station.

When a television antenna is mounted on a non-directional standard broadcast antenna, new resistance measurements must be made of the standard broadcast antenna after installation and testing of the television antenna. During the installation and until the new resistance determination is approved, the standard broadcast station licensee should apply for authority (informal application) to operate by the indirect method of power determination. The television license application will not be considered until the application form concerning resistance measurements is filed for the standard broadcast station.

When a television antenna is mounted on an element of a standard broadcast directional antenna, a full engineering study concerning the effect of the television antenna on the directional pattern must be filed with the application concerning the standard broadcast station. Depending upon the individual case, the Commission may require readjustment and certain field intensity measurements of the standard broadcast station following the completion of the television antenna system.

When the proposed television antenna is to be mounted on a tower in the vicinity of a standard broadcast directional array and it appears that the operation of the directional antenna system may be affected, an engineering study must be filed with the television application concerning the effect of the television antenna on the directional pattern. Readjustment and field intensity measurements of the standard broadcast station may be required following construction of the television antenna.

Information regarding data required in connection with standard broadcast directional antenna systems may be found in the Standards of Good Engineering Practice Concerning Standard Broadcast Stations.

E. In the event a common tower is used by two or more licensees for antenna and/or antenna supporting purposes, the licensee who is owner of the tower shall assume full responsibility for the installation and maintenance of any painting and/or lighting requirements.

In the event of shared ownership, one licensee shall assume such responsibility and advise the Commission accordingly.

F. Standard Lamps and Paints

When necessary for the protection of air navigation, the antenna and supporting structure shall be painted and illuminated in accordance with the specifications supplied by the Commission pursuant to Section 303 (q) of the Commission Act of 1934, as amended.

These individual specifications are issued for and attached to each authorization for an installation. The details of the specifications depend on the degree of hazard presented by the particular installation. The tower point shall be kept in good condition and repainted as often as necessary to maintain this condition.

General information regarding painting and lighting requirements is contained in the Obstruction Marking Manual available from the Civil Aeronautics Administration, Washington, (25) D.C.

9. Transmitters and Associated Equipment

A. Visual transmitter design

The general design of television broadcast visual transmitting equipment shall be in accordance with the following principles and specifications:

(1) The overall attenuation characteristics of the transmitter measured in the antenna transmission line, after the vestigal side band filters, shall not be greater than

2 db at 0.5 Mc
2 db at 1.25 Mc
3 db at 2.0 Mc
6 db at 3.0 Mc
12 db at 3.5 Mc

below the ideal demodulated curve (See Appendix III). The curve shall be substantially smooth between these specified points exclusive of the region from 0.75 Mc to 1.25 Mc 1/

(2) The field strength or voltage of the lower side band as radiated or dissipated and measured as described in (3) below shall not be greater than -20 db for a modulating frequency of 1.25 Mc or greater. 1/

(3) The attenuation characteristics of a visual transmitter shall be measured by application of a modulating signal to the transmitter input terminals in place of the normal composite television video signal. The signal applied shall be a composite signal composed of a synchronizing signal to establish peak output voltage plus a variable frequency sine wave voltage occupying the interval between synchronizing pulses. The axis of the sine wave in the composite signal observed in the output monitor shall be maintained at an amplitude 0.5 of the voltage at synchronizing peaks. The amplitude of the sine wave input shall be held at a constant value. This constant value should be such that at no modulating frequency does the maximum excursion of the sine wave, observed in the composite output signal monitor, exceed the value 0.75 of peak output voltage. The amplitude of the 100 kilocycle sideband shall be measured and designated zero db as a basis for comparison. The modulation signal frequency shall then be varied over the desired range and the field strength or signal voltage of the corresponding sidebands measured.

As an alternate method of measuring, in those cases in which the automatic d-c insertion can be replaced by manual control, the above characteristic may be taken by the use of a video sweep generator and without the use of pedestal synchronizing pulses. The d-c level shall be set for mid-characteristic operation. 1/

(4) The radio frequency signal, as radiated, shall have an envelope as would be produced by a modulating signal in conformity with Appendix I, as modified by vestigial operation specified by Appendix II.

(5) The time interval between the leading edges of successive horizontal pulses shall vary less than one half of one per cent of the average interval.

1/ In the case of (1) above, output measurement shall be made with the transmitter operating into a dummy load of pure resistance and the demodulated voltage measured across this load. The ideal demodulated curve is that shown in Appendix III.
In the case of (2) above, field strength measurements are desired. It is anticipated that these may not yield data which is consistent enough to prove compliance with the attenuation standards prescribed above. In that case, measurements with a dummy load of pure resistance together with data on the antenna characteristics shall be taken in place of overall field measurements. The synchronizing signal referred to in those paragraphs means either a standard synchronizing wave form or any pulse that will properly set the peak.

(6) The rate of change of the frequency of recurrence of the leading edges of the horizontal synchronizing signals shall be not greater than 0.15 per cent per second, the frequency to be determined by an averaging process carried out over a period of not less than 20, nor more than 100 lines, such lines not to include any portion of the vertical blanking a signal.

B. Aural transmitter design

The general design of the aural transmitting equipment associated with a television station shall be in accordance with the following principles and specifications:

(1) The transmitter shall operate satisfactorily with a frequency of swing of $\pm$ 25 kilocycles, which is considered 100% modulation. It is recommended, that the transmitter be designed to operate satisfactorily with a frequency swing of at least $\pm$ 40 kilocycles.

(2) The transmitting system (from input terminals of microphone pre-amplifier, through audio facilities at the studio, through telephone lines or other circuits between studio and transmitter, through audio facilities at the transmitter, but excluding equalizers for the correction of deficiencies in microphone response) shall be capable of transmitting a band of frequencies from 50 to 15,000 cycles. Pre-emphasis shall be employed in accordance with the impedance-frequency characteristic of a series inductance-resistance network having a time constant of 75 microseconds (See Appendix VI). The deviation of the system response from the standard pre-emphasis curve shall lie between two limits as shown by Appendix VI. The upper of these limits shall be uniform (no deviation) from 50 to 15,000 cycles. The lower limit shall be uniform from 100 to 7500 cycles, and three db below the upper limit, from 100 to 50 cycles the lower limit shall fall from three db limit at a uniform rate of one db per octave (four db at 50 cycles), from 7500 to 15,000 cycles the lower limit shall fall from the three db limit at a uniform rate of two db per octave (five db at 15,000 cycles).

(3) At any modulating frequency between 50 and 15,000 cycles and at modulation percentage of 25%, 50% and 100%, the combined audio frequency harmonics measured in the output of the system shall not exceed the root-mean-square values given in the following table:

Modulating frequency	Distortion
50 to 100 cycles	3.5%
100 to 7500 cycles	2.5%
7500 to 15000 cycles	3.0%

Measurements shall be made employing 75 microsecond de-emphasis in the measuring equipment and 75 microsecond per-emphasis in the transmitting equipment, and without compression if a compression amplifier is employed. Harmonics shall be included to 30 kc.*

*Measurements of distortion using de-emphasis in the measuring equipment are not practical at the present time for the range 7500 to 15,000 cycles for 25 and 50 per cent modulation. Therefore, measurements should be made at 100% modulation and on at least the following modulating frequencies: 50, 100, 400, 1,000, 5,000, 10,000 and 15,000 cycles. At 25 and 50% modulation measurements should be made on at least the following modulating frequencies: 50, 100, 400, 1,000 and 5,000 cycles.

It is recommended that none of the three main divisions of the system (transmitter, studio to transmitter circuit, and audio facilities) contribute over one-half of these percentages, since at some frequencies the total distortion may become the arithmetic sum of the distortions of the divisions.

(4) The transmitting system output noise level (frequency modulation) in the band of 50 to 15,000 cycles shall be at least 55 db. below the audio frequency level representing a frequency swing of $\pm$ 25 kc.**

(5) The transmitting system output noise level(amplitude modulation) in the band of 50 to 15,000 cycles shall be at least 50 db. below the level representing 100% amplitude modulation.**

(6) If a limiting or compression amplifier is employed, precaution should be maintained in its connection in the circuit due to the use of pre-emphasis in the transmitting system.

C. Design applicable to both visual and aural transmitters.

In addition to design features applicable to the individual transmitters, the general design of television broadcast (visual and aural) transmitting equipment shall be in accordance with the following principles and specifications:

(1) Automatic means shall be provided in the transmitters to maintain the authorized carrier frequencies within the allowable tolerance. ($\pm$ .002%)

(2) The transmitters shall be equipped with suitable indicating instruments for the determination of operating power and with other instruments as are necessary for proper adjustment, operation, and maintenance of the equipment.

(3) Adequate provision shall be made for varying the output power of the transmitters to compensate for excessive variations in line voltage or for other factors affecting the output powers.

(4) Adequate provisions shall be provided in all component parts to avoid overheating at the rated maximum output powers.

(5) Means should be provided for connection and continuous operation of approved frequency and modulation monitors.

D. Construction.

In general, the transmitters shall be constructed either on racks and panels or in totally enclosed framed protected as required by article 810 of the National Electrical Code and as set forth below:

The pertinent sections of article 810 of the National Electrical Code reads as follows:
"8191. General. - Transmitters shall comply with the following:

**For the purpose of these measurements the visual transmitter should be inoperative since the exact amount of noise permissible from that source is not known at this time.

a. Enclosing. - The transmitter shall be enclosed in a metal frame or grille, or separated from the operating space by a barrier or other equivalent means, all metallic parts of which are effectively connected to ground.

b. Grounding of controls. - All external metallic handles and controls accessible to the operating personnel shall be effectively grounded. No circuit in excess of 150 volts shall have any parts exposed to direct contact. A complete dead-front type of switchboard is preferred.

c. Interlocks on doors. - All access doors shall be provided with interlocks which will disconnect all voltages exceeding 350 volts when any access door is opened."

(1) Means shall be provided for making all tuning adjustments, requiring voltages in excess of 350 volts to be applied to the circuit, from the front of the panels with all access doors closed.

(2) Proper bleeder resistors or other automatic means shall be installed across all the capacitor banks to lower any voltage which may remain accessible with access door open to less than 350 volts within two seconds after the access door is opened.

(3) All plate supply and other high voltage equipment, including transformers, filters, rectifiers and motor generators, shall be protected so as to prevent injury to operating personnel.

(a) Commutator guards shall be provided on all high voltage rotating machinery. Coupling machinery. Coupling guards should be provided on motor generators.

(b) Power equipment and control panels of the transmitters shall meet above requirements (exposed 220 volt AC switching equipment on the front of the power control panels is not recommended but is not prohibited).

(c) Power equipment located at a television broadcast station not directly associated with the transmitters (not purchased as part of same), such as power distribution panels, are not under the jurisdiction of the Commission; therefore Section 3.654 does not apply.

(4) Metering equipment

(a) All instruments having more than 1,000 volts potential to ground on the movement shall be protected by a cage or cover in addition to the regular case. (Some instruments are designed by the manufacturers to operate safely with voltages in excess of 1,000 volts on the movement. If it can be shown by the manufacturer's rating that the instrument will operate safely at the applied potential, additional protection is not necessary).

(b) In case the plate voltmeters are located on the low potential side of the multiplier resistors with the potential of the high potential terminal of the instruments at or less than 1,000 volts above ground, no protective case is required. However, it is good practice to protect voltmeters subject to more than 5,000 volts with suitable over-voltage protective devices across the instrument terminals in case the winding opens.

(c) Transmission line meters and any other radio frequency instrument which may be necessary for the operator to read shall be so installed as to be easily and accurately read without the operator having to risk contact with circuits carrying high potential radio frequency energy.

(d) It is recommended that component parts comply as much as possible with the component specifications designated by the Army-Navy Electronics Standards Agency.

E. Wiring and Shielding

(1) The transmitter panels or units shall be wired in accordance with standard practice, such as insulated leads properly cabled and supported, concentric lines or rigid bus bar properly insulated and protected.

(2) Wiring between units of the transmitters, with the exception of circuits carrying radio frequency energy or video energy, shall be installed in conduits or approved fiber or metal raceways to protect it from mechanical injury.

(3) Circuits carrying radio frequency or video energy between units shall be either coaxial, two wire balanced lines, or properly shielded.

(4) All stages or units shall be adequately shielded and filtered to prevent interaction and radiation.

(5) The frequency and modulation monitors and associated radio frequency lines to the transmitter shall be thoroughly shielded.

F. Installation

(1) The installation shall be made in suitable quarters.

(2) Since an operator must be on duty during operation, suitable facilities for his welfare and comfort shall be provided.

G. Spare tubes

A spare tube of every type employed in the transmitters and frequency modulation monitors shall be kept on hand at the equipment location. When more than one tube of any type are employed, the following table determines the number of spares of that type required:

Number of each type employed:	Spares required
1 or 2	1
3 to 5	2
6 to 8	3
9 or more	4

An accurate circuit diagram and list of required spare tubes, as furnished by the manufacture of the equipment, shall be supplied and retained at the transmitter location.

H. Operation

In addition to specific requirements of the rules governing television broadcast stations, the following operating requirements are specified:

(1) Spurious emission, including radio frequency harmonics, shall be maintained at as low a level as the state of the art permits.

(2) If a limiting or compression amplifier is used in conjunction with the aural transmitter, precautions should be maintained in its use due to pre-emphasis in the transmitting system.

I. Studio Equipment

Studio equipment shall be subject to all the above requirements where applicable except as follows:

(1) If properly covered by an underwriters' certificate, it will be considered as satisfying safety requirements.

(2) Section 8191 of Article 810 of the National Electrical Code shall apply for voltages only in excess of 500 volts.

No specific requirements are made relative to the design and acoustical treatment of studios, particularly the main studio, shall be compatible with the required performance characteristics of television broadcast stations.

10. Indicating Instruments

A. A television broadcast station shall be equipped with suitable indicating instruments of accepted accuracy to measure the direct plate voltage and current of the last radio stage of the visual and aural transmitters and an instrument for reading the transmission line of both transmitters.

The following requirements and specifications shall apply to indicating instruments used by television broadcast stations in compliance with this rule:

(1) Length of scale shall be not less than 2 3/10 inches.

(2) Accuracy shall be at least 2 per cent of the full scale reading.

(3) Scale shall have at least 40 divisions.

(4) Full scale reading shall be not greater than five times the minimum normal indications.

No specifications are prescribed at this time regarding the peak indicating device required by Section 11B (1) of these standards.

B. No instruments indicating the plate current or plate voltage of the last radio stage shall be changed or replaced without written authority of the Commission, except by instruments of the same maximum scale readings and accuracy. Requests for authority to use an instrument of different maximum scale reading and/or accuracy shall be made by letter or telegram giving the manufacturer's name, type number, and full scale reading of the proposed instrument and the values of current or voltage the instrument will be employed to indicate. Requests for temporary authority to operate without an instrument or with a substitute instrument may be made by letter or telegram stating the necessity therefore and the period involved.

C. No required instrument, the accuracy of which is questionable, shall be employed. Repairs and calibration of instruments shall be made by the manufacturer, or by an authorized instrument repair service of the manufacturer, or by some other properly qualified or equipped instrument repair service. In any case, the repaired instrument must be supplied with a certificate of calibration.

D. Recording instruments may be employed in addition to the indicating instruments to record the direct plate current and/or voltage to the last radio stage provided that they do not affect the operation of the circuits or accuracy of the indicating instruments. If the records are to be used in any proceeding before the Commission, as representative of operation, the accuracy must be the equivalent of the indicating instruments and the calibration shall be checked at such intervals as to insure the retention of such accuracy.

E. The function of each instrument used in the equipment shall be clearly and permanently shown on the instrument itself or on the panel immediately adjacent thereto.

II. Operating Power - Determination and Maintenance

A. Determination

(1) Visual transmitter

The average power shall be measured while operating into a dummy load of substantially zero reactance and a resistance equal to the transmission line surge impedance, while transmitting a standard black television picture. The peak power obtained by this method, multiplied by the factor 1.68. During this measurement the direct plate voltage and current of the last radio stage and the peak output voltage or current shall be read for use below.

(2) Aural transmitter

The operating power of the aural transmitter shall be determined by the indirect method. This is the product of the plate voltage (Ep) and the plate current (Ip) of the last radio stage, and an efficiency factor, F. That is:

$$\text{Operating power} = Ep \times Ip \times F$$

The efficiency factor, F, shall be established by the transmitter manufacturer for each type of transmitter for which he requests FCC approval, and shall be shown in the instruction books supplied to the customer with each transmitter. In the case of composite equipment the factor F shall be furnished to the Commission by the applicant along with a statement of the basis used in determining such factor.

B. Maintenance

(1) Visual Transmitter

The peak power shall be monitored by a peak reading device which reads proportionally to other voltage or current on the transmission line operating into the antenna, the meter to be calibrated during the measurement described in A (1) above. The operating power as so monitored shall be maintained as near as practicable to the authorized operating power and shall not exceed the limits of 10 per cent above and 20 per cent below the authorized power except in emergencies.

As a further check both plate voltage and plate current of the output stage shall be measured with a standard black television picture with the transmitter operating into the antenna. These values must agree substantially with corresponding readings taken under A (1) above.

(2) Aural Transmitter

The operating power of aural transmitters shall be maintained as near as practicable to the authorized operating power, and shall not exceed the limits of 10 percent above and 20 percent below the authorized power except in emergencies.

(3) In the event it becomes impossible to operate with the authorized power, the station may be operated with reduced power for a period of 10 days or less provided the Commission and the Inspector in Charge of the district in which the station is located shall be notified in writing immediately thereafter and also upon the resumption of the normal operating power. 3/

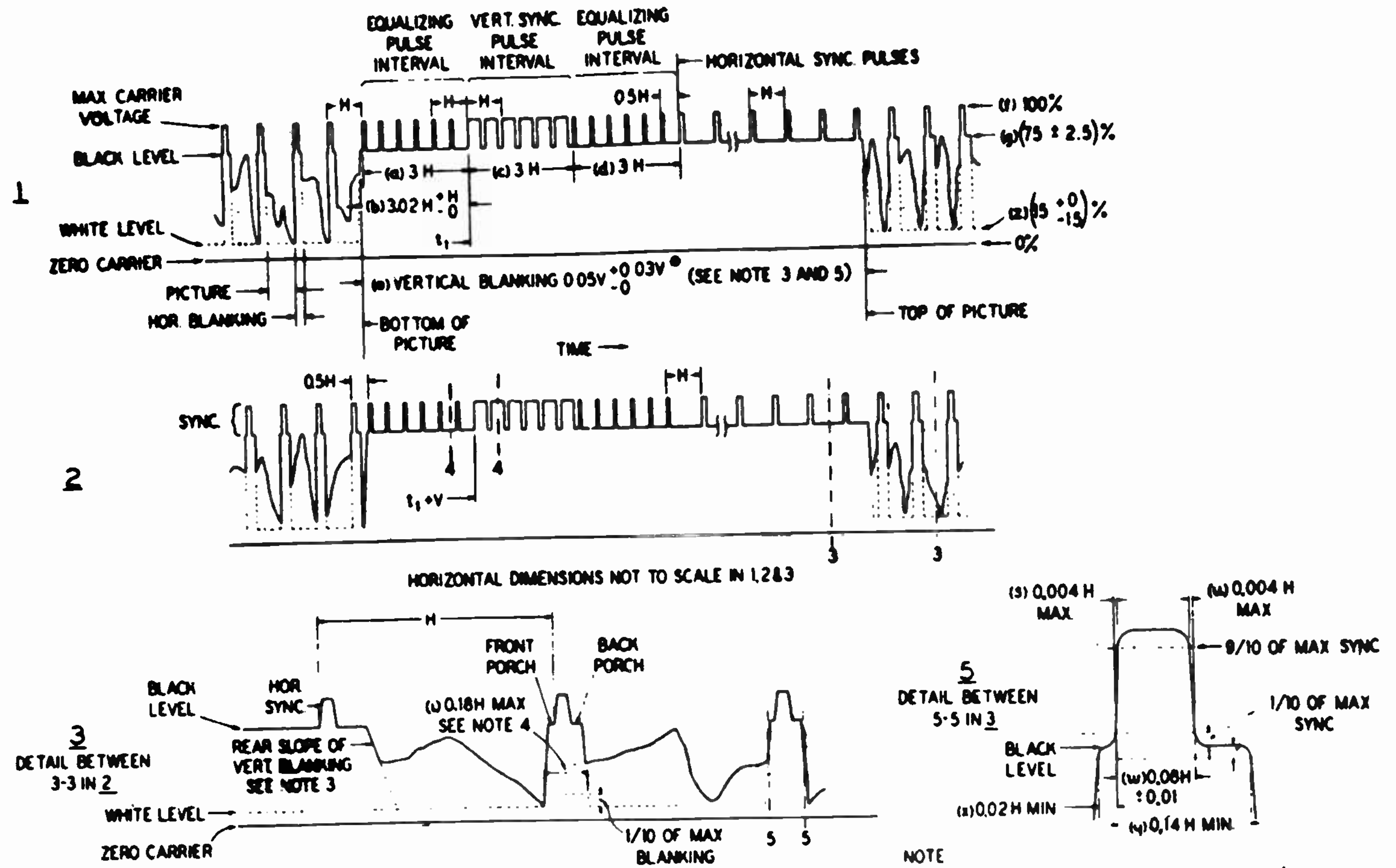
12. Auxiliary Transmitters

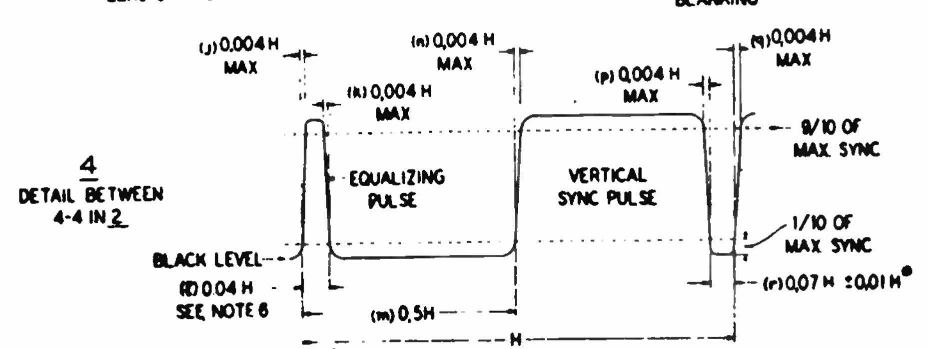
Auxiliary transmitters may not exceed the power rating of the main transmitters. As a general guide specifications for auxiliary transmitters should conform as much as possible to those of the main transmitters. No requirements are set forth at this time.

13 to 20, inclusive: These sections are in the process of being formulated.

3/ See Appendix 3 of Part I of the Rules and Regulations for addresses of Field Offices.

TELEVISION SYNCHRONIZING WAVEFORM





NOTE

1 - H = TIME FROM START OF ONE LINE TO START OF NEXT LINE.

2 - V = TIME FROM START OF ONE FIELD TO START OF NEXT FIELD.

3 - LEADING AND TRAILING EDGES OF VERTICAL BLANKING SHOULD BE COMPLETE IN LESS THAN 0.1 H.

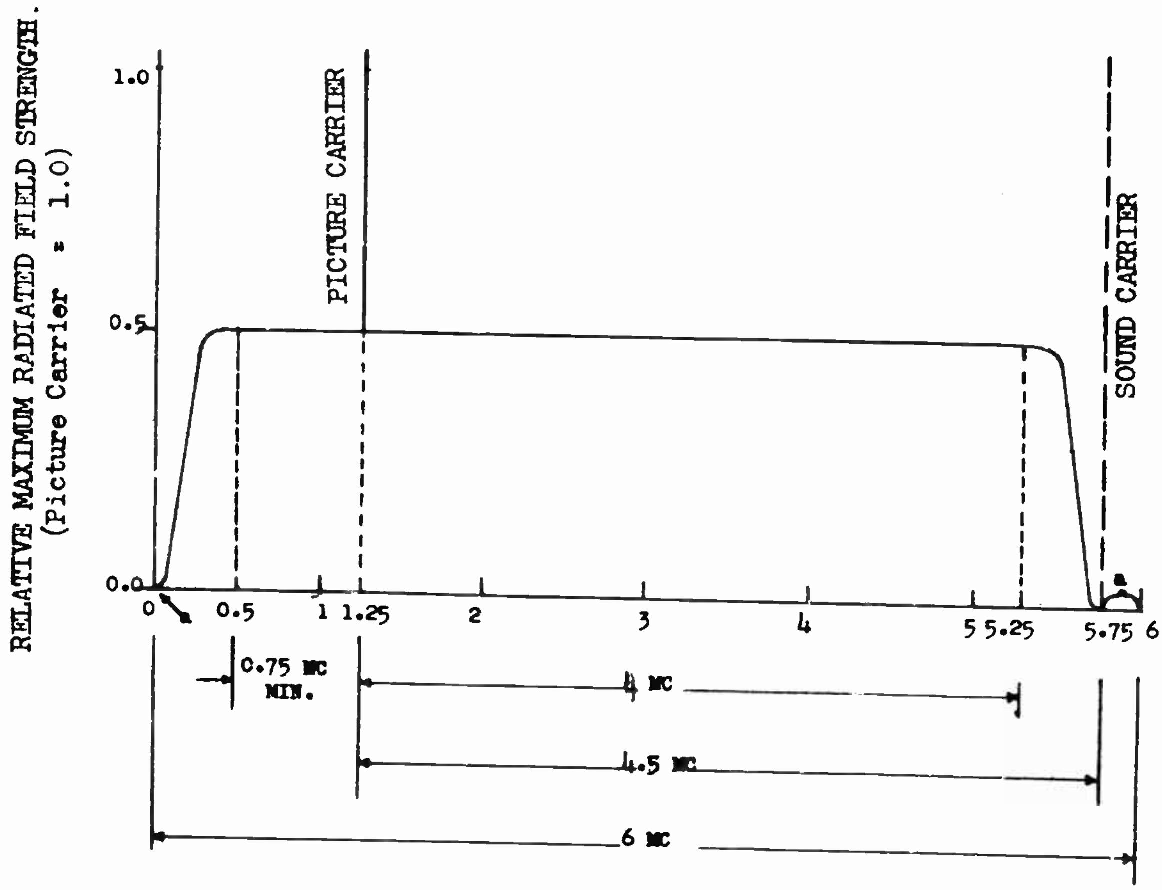
4 - LEADING AND TRAILING SLOPES OF HORIZONTAL BLANKING MUST BE STEEP ENOUGH TO PRESERVE MIN AND MAX VALUES OF (x + y) AND (i) UNDER ALL CONDITIONS OF PICTURE CONTENT.

*5 - DIMENSIONS MARKED WITH AN ASTERISK INDICATE THAT TOLERANCES GIVEN ARE PERMITTED ONLY FOR LONG TIME VARIATIONS, AND NOT FOR SUCCESSIVE CYCLES.

6 - EQUALIZING PULSE AREA SHALL BE BETWEEN 0.45 AND 0.5 OF THE AREA OF A HORIZONTAL SYNC PULSE.

7 - REFER TO TEXT FOR FURTHER EXPLANATIONS AND TOLERANCES.

IDEALIZED PICTURE TRANSMISSION AMPLITUDE CHARACTERISTIC

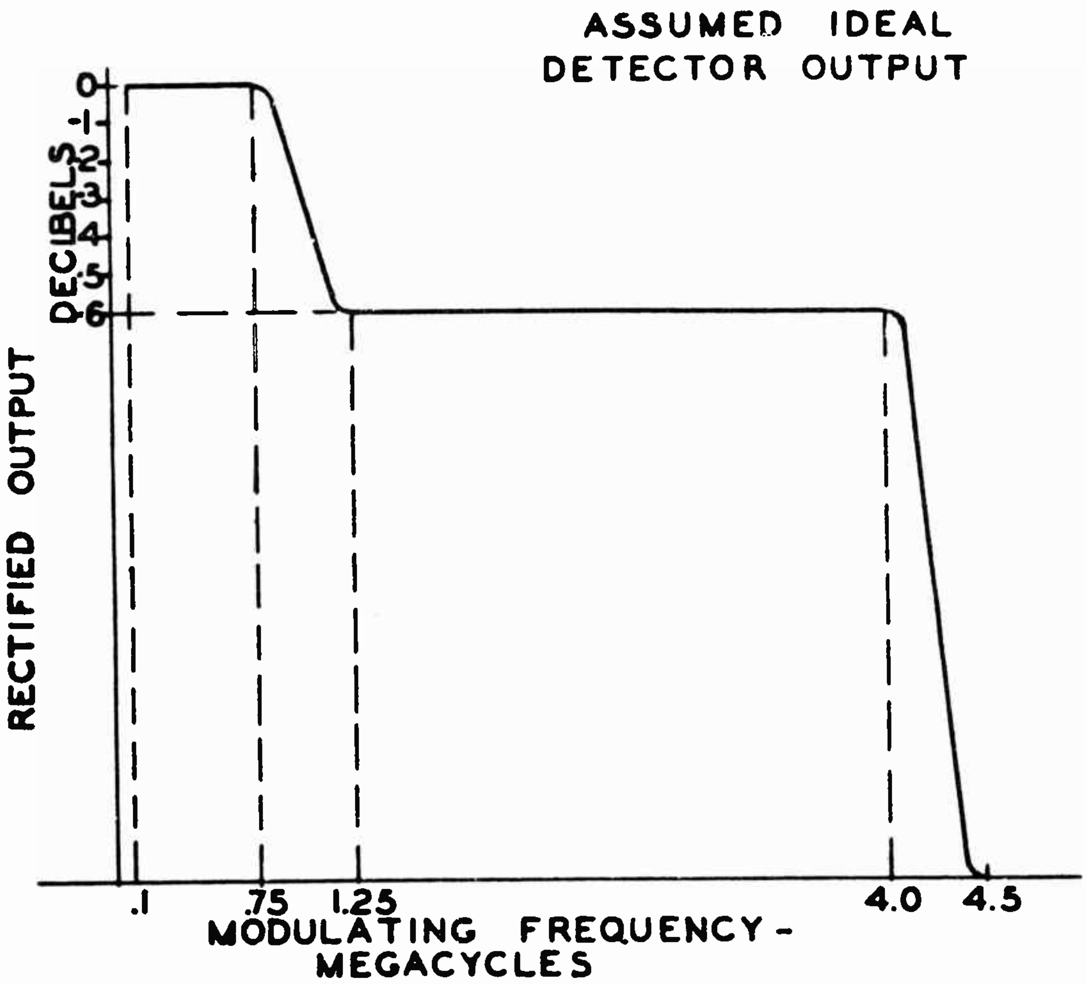


NOTES

a - See Section 9.A.(2) for relative field strength at these points.

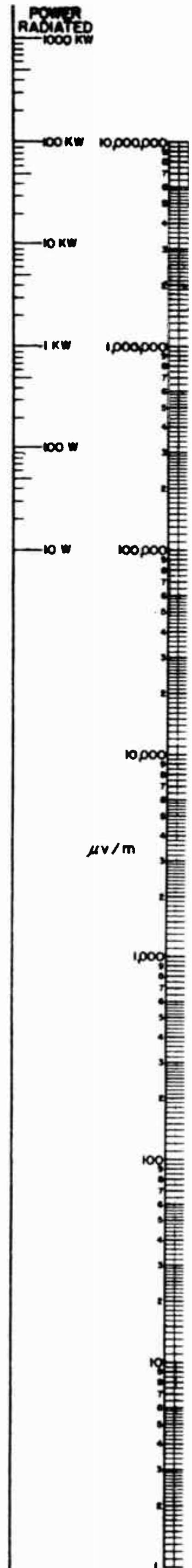
Drawing not to scale.

Appendix II

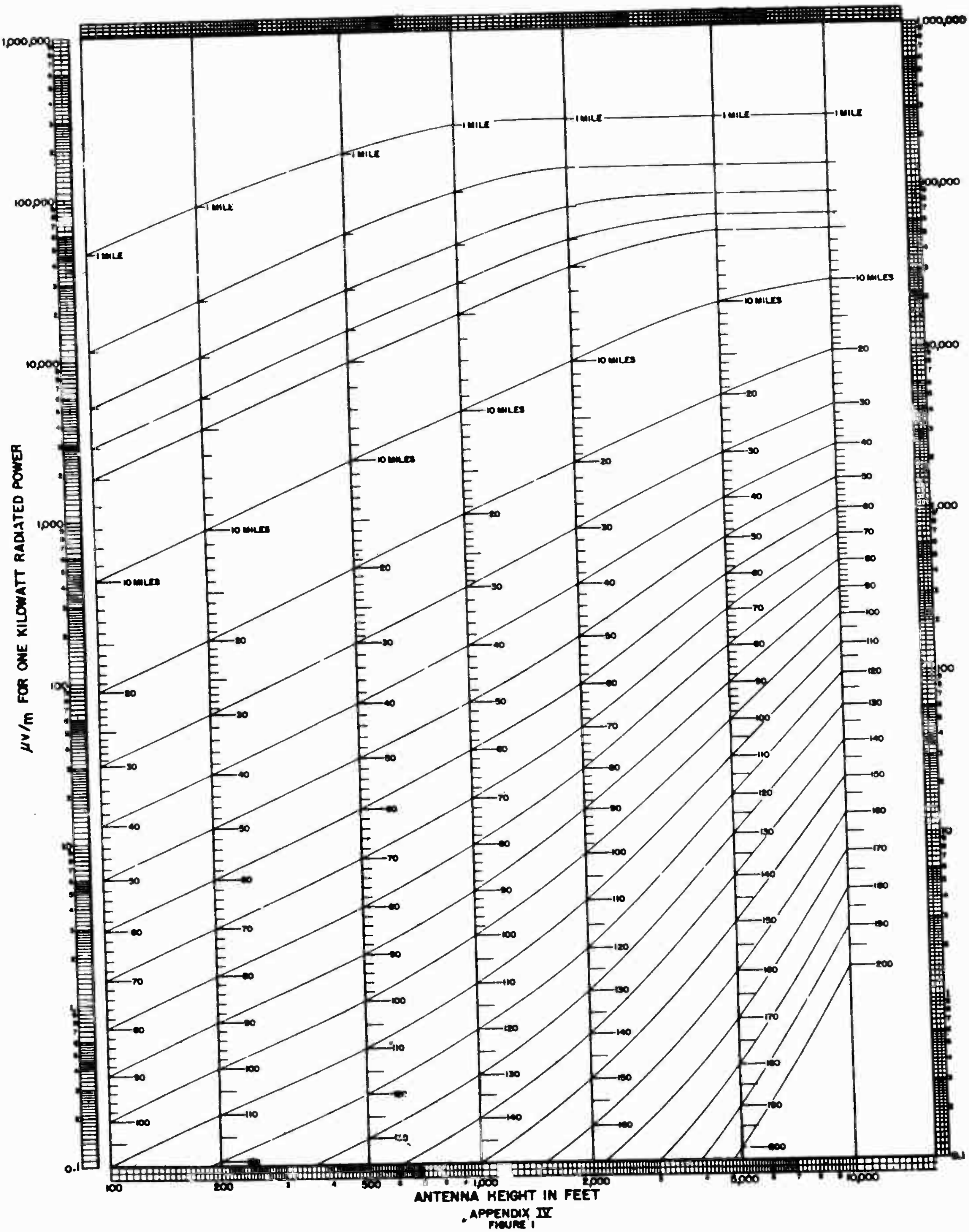


APPENDIX III

83787-1


POWER RADIATED
1000 KW
100 KW
10 KW
1 KW
100 W
10 W
10,000,000
1,000,000
100,000
10,000
μv/m
1,000
100
10

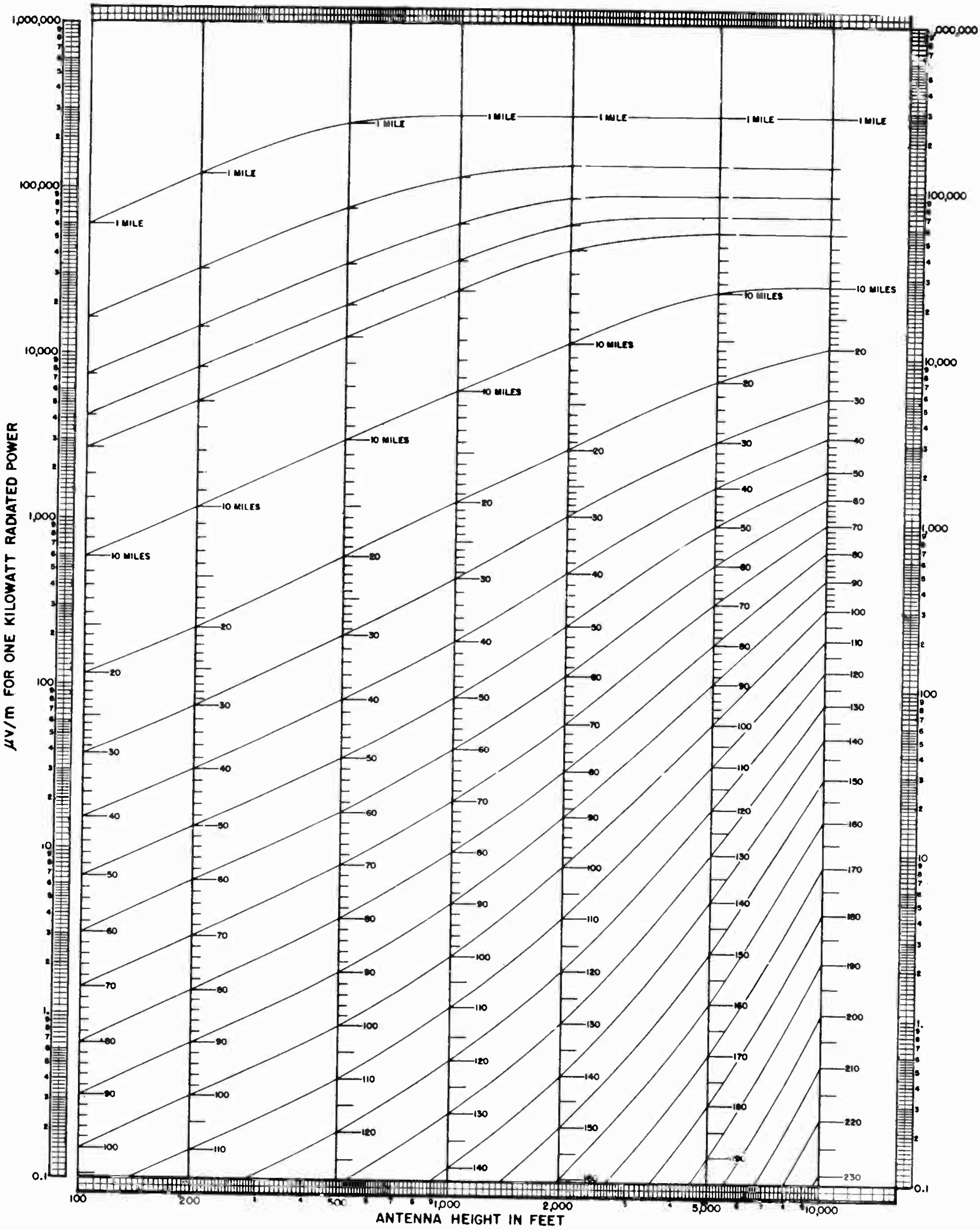
APPENDIX IV



APPENDIX IV
FIGURE I

GROUND WAVE SIGNAL RANGE FOR TELEVISION

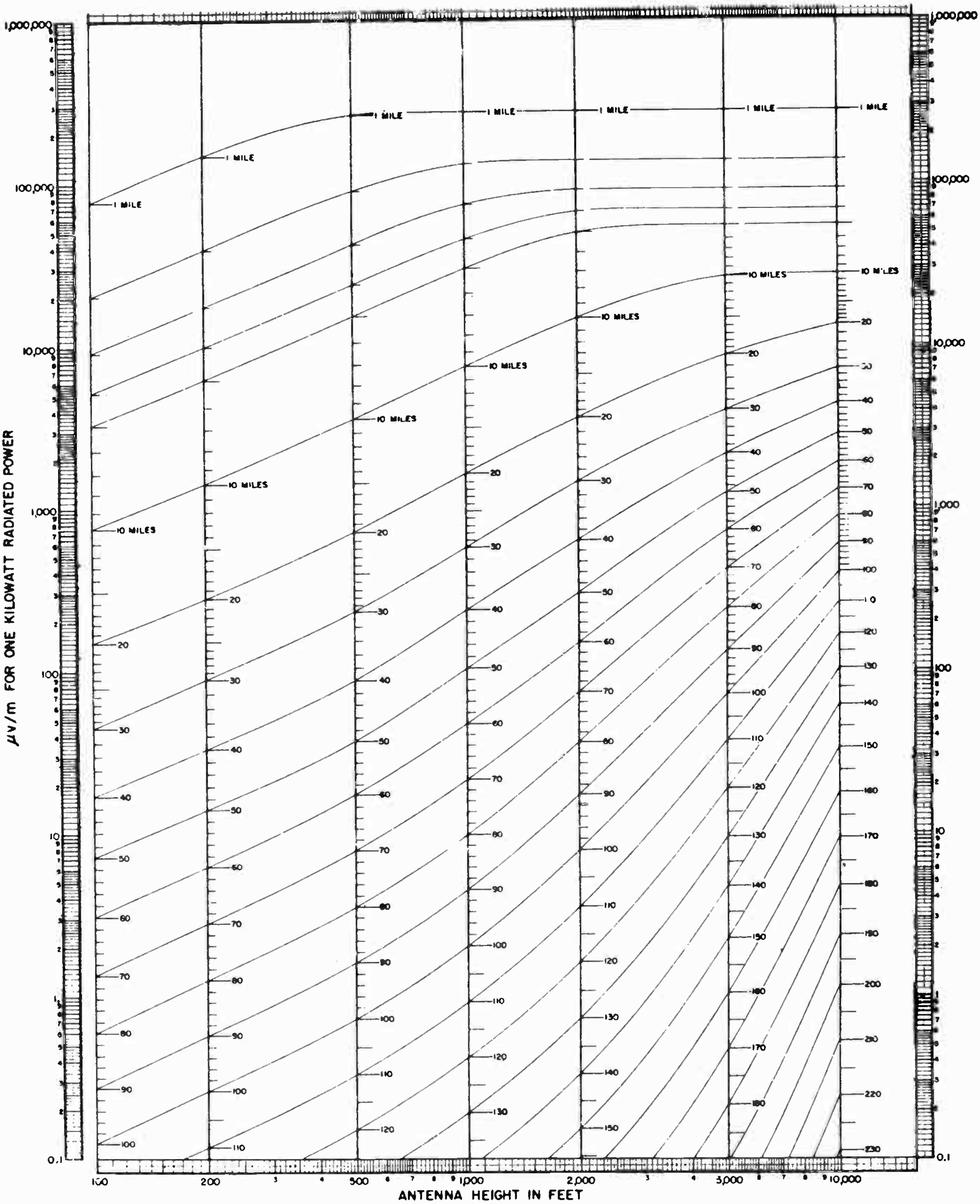
46 mc, $\sigma = 5 \times 10^{-14}$ e.m.u., $\epsilon = 15$, RECEIVING ANTENNA HEIGHT 30 FEET
FOR HORIZONTAL (AND APPROX. FOR VERTICAL) POLARIZATION



APPENDIX IV
FIGURE 2

GROUND WAVE SIGNAL RANGE FOR TELEVISION

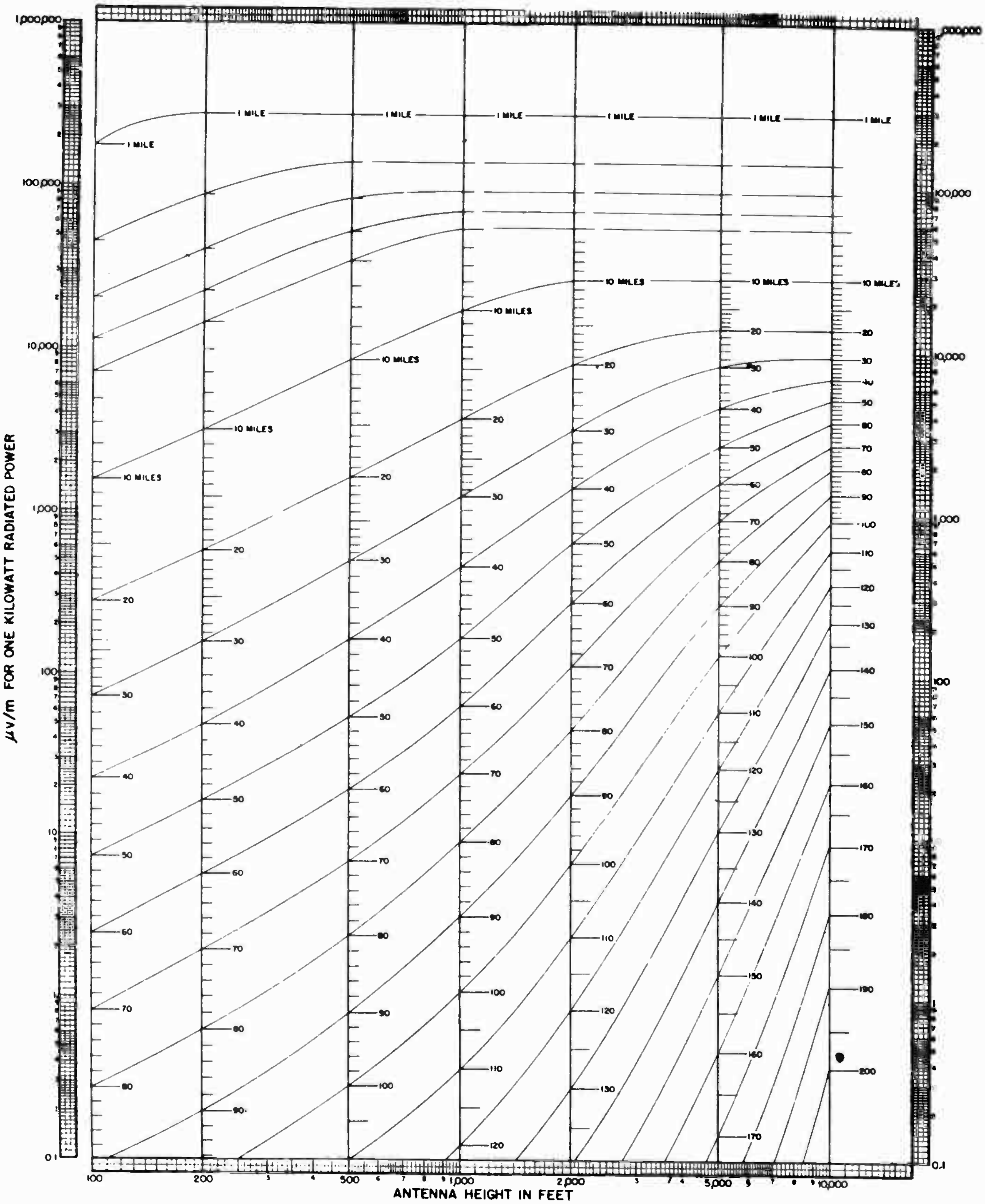
63 mc, $\sigma = 5 \times 10^{-14}$ e.m.u., $\epsilon = 15$, RECEIVING ANTENNA HEIGHT 30 FEET
FOR HORIZONTAL (AND APPROX. FOR VERTICAL) POLARIZATION



APPENDIX IV
FIGURE 3

GROUND WAVE SIGNAL RANGE FOR TELEVISION

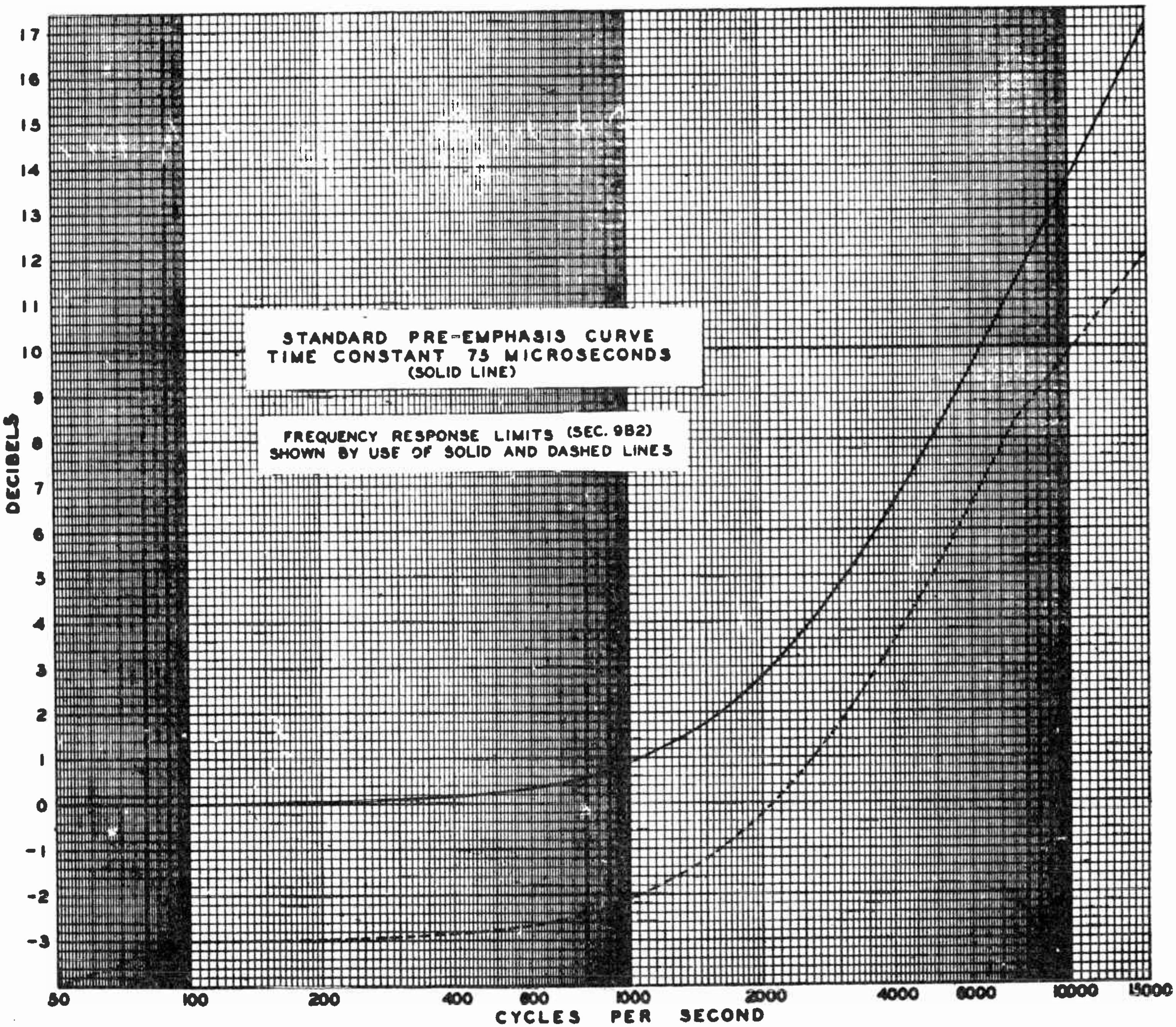
82 mc, $\sigma = 5 \times 10^{-14}$ e.m.u., $\epsilon = 15$, RECEIVING ANTENNA HEIGHT 30 FEET
FOR HORIZONTAL (AND APPROX. FOR VERTICAL) POLARIZATION



APPENDIX IV
FIGURE 4

GROUND WAVE SIGNAL RANGE FOR TELEVISION

195 mc, $\sigma = 5 \times 10^{-14}$ e.m.u., $\epsilon = 15$, RECEIVING ANTENNA HEIGHT 30 FEET
FOR HORIZONTAL (AND APPROX. FOR VERTICAL) POLARIZATION


STANDARD PRE-EMPHASIS CURVE
TIME CONSTANT 75 MICROSECONDS
(SOLID LINE)
FREQUENCY RESPONSE LIMITS (SEC. 9B2)
SHOWN BY USE OF SOLID AND DASHED LINES
DECIBELS
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
50
100
200
400
600
1000
2000
4000
6000
10000
15000
CYCLES PER SECOND

APPENDIX VI

RULES GOVERNING TELEVISION BROADCAST STATIONS

CLASSIFICATION OF TELEVISION STATIONS AND ALLOCATION OF FREQUENCIES

Numerical designation of television channels. - The channels or frequency bands set forth below are available for television broadcast stations.

Channel No.	Megacycles	Channel No.	Megacycles
1	44 - 50	7	174 - 180
2	54 - 60	8	180 - 186
3	60 - 66	9	186 - 192
4	66 - 72	10	192 - 198
5	72 - 82	11	198 - 204
6	82 - 88	12	204 - 210
		13	210 - 216

Sharing of Television Channels. - Channels 1 through 5 and 7 through 13 are available for assignment to radio services other than television upon a showing that no mutual interference will result.

Community Stations. - (a) A Community station is designed primarily for rendering service to the smaller metropolitan districts or principal cities. Television channel No. 1 is assigned exclusively for Community stations. Channels 2 to 13, inclusive, can also be used for Community stations provided such use complies with Section 3.606.

(b) The power of a community station may not exceed an effective radiated peak power of 1 kilowatt. The maximum antenna height for such stations shall be 500 feet above the average terrain as determined by methods prescribed in the Standards of Good Engineering Practice concerning Television Broadcast stations.

(c) The main studio of a Community station shall be located in the city or town served and the transmitter shall be located as near the center of the city as practicable.

Metropolitan stations. - (a) Metropolitan stations may be assigned to television channels 2 through 13, both inclusive. They are designed primarily to render service to a single metropolitan district or a principal city and to the rural area surrounding such metropolitan district or principal city.

(b) Metropolitan stations are limited to a maximum of 50 kilowatts effective radiated peak power with antenna having a height of 500 feet above the average terrain, as determined by the methods prescribed in Standards of Good Engineering Practice concerning television broadcast stations. Where higher antenna heights are available, they should be used, but in such cases the Commission may authorize less than 50 kilowatts effective radiated peak power so that the coverage (within the 5000 uv/m contour) shall be substantially similar to that which would be provided by 50 kilowatts effective radiated peak power and a 500 foot antenna. Where it is shown that an antenna height of 500 feet is not available, the Commission may authorize the use of a lower height antenna but will not permit an increase in radiated power in excess of 50 kilowatts. The service area of a Metropolitan station will not be protected beyond the 500 uv/m contour and such stations will be located in such a manner as to insure, insofar as possible, a maximum of television service to all listeners, whether urban or rural.

(c) The main studio for Metropolitan stations shall be located in the city or metropolitan district with which the station is associated and the transmitter should be located so as to provide the maximum service to the city or metropolitan district served.

Rural Stations. - (a) Licensees of Metropolitan stations or applicants who desire to qualify as licensees of Rural stations must make a special showing to the Commission that they propose to serve an area more extensive than that served by a Metropolitan station and that the additional area served is predominantly rural in character. In addition, a showing must be made that such use of the channel will not cause objectionable interference to other television stations or prevent the assignment of other television stations where there is reasonable evidence of the probability of such station being located in the future.

(b) Channels 2 through 13 are available for assignment to Rural stations. The service area of Rural stations will be determined by the Commission.

(c) The main studio of Rural stations shall be located within the 500 uv/m contour.

RULES GOVERNING ADMINISTRATIVE PROCEDURE

Application for television stations. - Each applicant for a construction permit for a new television broadcast station, change in facilities of any existing television broadcast station, or television station license or modification of license shall file with the Commission in Washington, D.C., three copies of applications on the appropriate form designated by the Commission and a like number of exhibits and other papers incorporated therein and made a part thereof. Only the original copy need be sworn to. If the application is for a construction permit for a new television station, Form FCC No. 330 should be filed; for a television station license, Form FCC No. 331 should be filed; and for modification of a television station license or for change in facilities of an existing television station, Form FCC No. 333 should be filed.

Full disclosures. - Each application shall contain full and complete disclosures with regard to the real party or parties in interest, and their legal, technical, financial, and other qualifications, and as to all matters and things required to be disclosed by the application forms.

Installation or removal of apparatus. - Applications for construction permit or modification thereof, involving removal of existing transmitting apparatus and/or installation of new transmitting apparatus, shall be filed at least 60 days prior to the contemplated removal and/or installation.

Period of construction. - Each construction permit will specify a maximum of 60 days from the date of granting thereof as the time within which construction of the station shall begin, and a maximum of six months thereafter as the time within which construction shall be completed and a station ready for operation, unless otherwise determined by the Commission upon proper showing in any particular case.

Forfeiture of construction permits: extension of time. - (a) A construction permit shall be automatically forfeited if the station is not ready for operation within the time specified therein or within such further time as the Commission may have allowed for completion, and a notation of the forfeiture of any construction permit under this provision will be placed in the records of the Commission as of the expiration date.

(b) An application (Form FCC No. 701) for extension of time within which to construct a station shall be filed at least thirty days prior to the expiration date of such permit if the facts supporting such application for extension are known to the applicant in time to permit such filing. In other cases such application will be accepted upon a showing satisfactory to the Commission of sufficient reasons for filing within less than thirty days prior to the expiration date. Such applications will be granted upon a specific and detailed showing that the failure to complete was due to causes not under the control of the grantee, or upon a specific and detailed showing of other matters sufficient to justify the extension.

Equipment tests and proof of performance. - (a) Upon completion of construction of a television station in exact accordance with the terms of the construction permit, the technical provisions of the application therefore and the rules and regulations and standards of good engineering practice governing television stations and prior to filing of application for license, the permittee is authorized to test the equipment for a period not to exceed 90 days: Provided, that the inspector in charge of the district in which the station is located and the Commission are notified 2 days in advance of the beginning of tests.

(b) The Commission may notify the permittee to conduct no tests or may cancel, suspend, or change the date of beginning for the period of such tests as and when such action may appear to be in the public interest, convenience, and necessity.

(c) Within the 90 day period prescribed by this section for equipment tests, field intensity measurements in accordance with the methods prescribed in the Standards of Good Engineering Practice Concerning Television Broadcast Stations shall be submitted to the Commission. The Commission may grant extensions of time upon showing of reasonable need therefore.

Program tests. - (a) When construction and equipment tests are completed in exact accordance with the terms of the construction permit, the technical provisions of the application therefore, and the Rules and Regulations and Standards of Good Engineering Practice Governing Television Stations, and after an application for station license has been filed with the Commission showing the equipment to be in satisfactory operating condition, the permittee is authorized to conduct program tests in exact accordance with the terms of the construction permit for a period not to exceed 30 days: Provided, that the inspector in charge of the district in which the station is located and the Commission are notified 2 days in advance of the beginning of such tests.

(b) The Commission reserves the right to cancel such tests or suspend, or change the date of beginning for the period of such tests as and when such action may appear to be in the public interest, convenience, and necessity by notifying the permittee.

(c) The authorization for tests embodied in this section or section 3.616 shall not be construed as constituting a license to operate but as a necessary part of the construction.

Normal license period. - All television broadcast station licenses will be issued so as to expire at the hour of 3 a.m. E.S.T. and will be issued for a normal license period of 1 year.

License, simultaneous modification and renewal. - When an application is granted by the Commission necessitating the issuance of a modified license less than 60 days prior to the expiration date of the license sought to be modified, and an application for renewal of said license is granted subsequent or prior thereto (but within 30 days of expiration of the present license) the modified license as well as the renewal license shall be issued to conform to the combined action of the Commission.

Renewal of license. - (a) Unless otherwise directed by the Commission, each application for renewal of a television station license shall be filed at least 60 days prior to the expiration date of the license sought to be renewed (Form FCC No. 311). No application for renewal of license of a television broadcast station will be considered unless there is on file with the Commission, the information currently required by Sections 1.301 - 1.304, reference to which by date and file number shall be included in the application.

(b) Whenever the Commission regards an application for a renewal of a television station license as essential to the proper conduct of a hearing or investigation, and specifically directs that it be filed by a certain date, such application shall be filed within the time thus specified. If the licensee fails to file such application within the prescribed time, the hearing or investigation shall proceed as if such renewal application had been received.

Temporary extension of station licenses. - Where there is pending before the Commission any application, investigation, or proceeding which after hearing, might lead to or make necessary the modification of, revocation of, or refusal to renew an existing television license, the Commission may, in its discretion, grant a temporary extension of such license: Provided however, that no such temporary extension shall be construed as a finding by the Commission that the operation of any radio station thereunder will serve public interest, convenience, and necessity beyond the express terms of such temporary extension of license: And provided further, that such temporary extension of license will in no wise affect or limit the action of the Commission with respect to any pending application or proceeding.

Repetitious applications - (a) Where an application has been afforded an opportunity to be heard with respect to a particular application for a new television broadcast station, or for change of existing service or facilities, and the Commission has, after hearing or default, denied the application or dismissed it with prejudice, the Commission will not consider another application for a station of the same class to serve in whole or in part the same area, by the same applicant or by his successor or assignee, or on behalf of or for the benifit of the original parties in interest, until after the lapse of 12 months from the effective date of the Commission's order.

(b) Where an appeal has been taken from the action of the Commission in denying a particular application, another application for the same class of broadcast station and for the same area, in whole or in part, filed by the same applicant or by his successor or assignee, or on behalf or for the benefit of the original parties in interest, will not be considered until the final disposition of such appeal.

Assignment or transfer of control. - (a) Voluntary: Application for consent to voluntary assignment of a television station construction permit or license or for consent to voluntary transfer of control of a corporation holding a television station construction permit or license shall be filed with the Commission on Form FCC No. 314 (assignment of license) or Form FCC No. 315 (transfer of control) at least 60 days prior to the contemplated effective date of assignment or transfer of control.

(b) Involuntary: In the event of the death or legal disability of a permittee or licensee, or a member of a partnership, or a person directly or indirectly in control of a corporation, which is a permittee or licensee:

(1) the Commission shall be notified in writing promptly of the occurrence of such death or legal disability, and

(2) within thirty days after the occurrence of such death or legal disability, application on Form FCC No. 314 or 315 shall be filed for consent to involuntary assignment of such television station permit or license or for involuntary transfer of control of such corporation to a person or entity legally qualified to succeed to the foregoing interests under the law of the place having jurisdiction over the estate involved.

RULES RELATING TO LICENSING POLICIES

Exclusive affiliation of station. - No license shall be granted to a television broadcast station having any contract, arrangement, or understanding, express or implied with a network organization 1/ under which the station is prevented or hindered from, or penalized for, broadcasting the programs of any other network organization.

Territorial exclusivity. - No license shall be granted to a television broadcast station having any contract, arrangement, or understanding, express or implied, with a network organization which prevents or hinders another broadcast station serving substantially the same area from broadcasting the network's programs not taken by the former station, or which prevents or hinders another broadcast station serving a substantially different area from broadcasting any program of the network organization. This regulation shall not be construed to prohibit any contract, arrangement, or understanding between a station and a network organization pursuant to which the station is granted the first call in its primary service area upon the programs of the network organization.

Term of affiliation. - No license shall be granted to a television broadcast station having any contract, arrangement, or understanding, express or implied, with a network organization which provides, by original terms, provisions for renewal, or otherwise for the affiliation of the station with the network organization for a period longer than two years: Provided, that a contract, arrangement, or understanding for a period up to two years, may be entered into within six months prior to the commencement of such period.

Option time. - No license shall be granted to a television broadcast station which options 2/ for network programs any time subject to call on less than 56 days notice, or more time than a total of three hours 3/ within each or four segments of the broadcast day, as herein described. The broadcast day is divided into 4 segments, as follows: 8:00 a.m. to 1:00 p.m.;

1/ The term "network organization" as used herein includes national and regional network organizations. See Chapter VII, J, of Report on Chain Broadcasting.

2/ As used in this section, an option is any contract, arrangement, or understanding express or implied, between a station and a network organization which prevents or hinders the station from scheduling programs before the network agrees to utilize the time during which such programs are scheduled, or which requires the station to clear time already scheduled when the network organization seeks to utilize the time.

3/ All time options permitted under this section must be specified clock hours, expressed in terms of any time system set forth in the contract agreed upon by the station and network organization. Shifts from daylight saving to standard time or vice versa may or may not shift the specified hours correspondingly as agreed by the station and network organization.

1:00 p.m. to 6:00 p.m.; 6:00 p.m. to 11:00 p.m.; 11:00 p.m. to 8:00 a.m. 1/ Such options may not be exclusive as against other network organizations and may not prevent or hinder the station from optioning or selling any or all of the time covered by the option, or other time, to other network organizations.

Right to reject programs. - No license shall be granted to a television broadcast station having any contract, arrangement, or understanding, express or implied, with a network organization which (a) with respect to programs offered pursuant to an affiliation contract, prevents or hinders the station from rejecting or refusing network programs which the station reasonably believes to be unsatisfactory or unsuitable; or which (b) with respect to network programs so offered or already contracted for, prevents the station from rejecting or refusing any program which, in its opinion, is contrary to the public interest, or from substituting a program of outstanding local or national importance.

Network ownership of stations. - No license shall be granted to a network organization, or to any person directly or indirectly controlled by or under common control of a network organization, for a television broadcast station in any locality where the existing television broadcast stations are so few or of such unequal desirability (in terms of coverage, power, frequency, or other related matters) that competition would be substantially restrained by such licensing.

Dual network operation. - No license shall be issued to a television broadcast station affiliated with a network organization which maintains more than one network of television broadcast stations: Provided, that this regulation shall not be applicable if such networks are not operated simultaneously, or if there is no substantial overlap in the territory served by the group of stations comprising each such network.

Control by networks of station rates. - No license shall be granted to a television broadcast station having any contract, arrangement, or understanding express or implied with a network organization under which the station is prevented or hindered from, or penalized for, fixing or altering its rates for the sale of broadcast time for other than the network's programs.

Use of common antenna site. - No television license or renewal of a television license will be granted to any person who owns, leases, or controls a particular site which is peculiarly suitable for television broadcasting in a particular area and (1) which is not available for use by other television licensees; and (2) no other comparable site is available in the area; and (3) where the exclusive use of such site by the applicant or licensee would unduly limit the number of television stations that can be authorized in a particular area or would unduly restrict competition among television stations.

Multiple ownership. - (a) No person (including all persons under common control) 2/ shall, directly or indirectly, own, operate, or control more than one television broadcast station that would serve substantially the same service area as another television broadcast station owned, operated, or controlled by such person.

(b) No person (including all persons under common control) shall, directly or indirectly, own, operate, or control more than one television broadcast station, except upon a showing (1) that such ownership, operation, or control would foster competition among television broadcast

1/ These segments are to be determined for each station in terms of local time at the location of the station but may remain constant throughout the year regardless of shifts from standard to daylight saving time or vice versa.

2/ The word "control" as used herein is not limited to majority stock ownership, but includes actual working control in whatever manner exercised.

stations or provide a television broadcasting service distinct and separate from existing services, and (2) that such ownership, operation, or control would not result in the concentration of control of television broadcasting facilities in a manner inconsistent with public interest, convenience, or necessity; provided, however, that the Commission will consider the ownership, operation, or control of more than five television broadcast stations to constitute the concentration of control of television broadcasting facilities in a manner inconsistent with public interest, convenience, or necessity.

RULES RELATING TO EQUIPMENT

Transmitter power. - The rated power and operating power range of transmitters shall be in accordance with the Standards of Good Engineering Practice concerning Television Broadcast Stations.

Frequency monitors. - The licensee of each television broadcast station shall have in operation at the transmitters frequency monitors independent of the frequency control of the transmitters.

Modulation monitors. - The licensee of each television broadcast station shall have in operation at the transmitter a modulation monitor for the aural transmitter. There shall also be sufficient monitoring equipment for the visual signal to determine that the signal complies with the Standards of Good Engineering Practice concerning Television Broadcast Stations.

Required transmitter performance. - The construction, installation, operation, and performance of the television broadcast transmitter system shall be in accordance with the Standards of Good Engineering Practice concerning Television Broadcast Stations.

Auxiliary transmitter. - Upon showing that a need exists for the use of auxiliary transmitters in addition to the regular transmitters of a television station, a license therefor may be issued provided that:

(a) Auxiliary transmitters may be installed either at the same location as the main transmitters or at another location.

(b) A licensed operator shall be in control whenever auxiliary transmitters are placed in operation.

(c) The auxiliary transmitters shall be maintained so that they may be put into immediate operation at any time for the following purposes;

(1) The transmission of the regular programs upon the failure of the main transmitters.

(2) The transmission of regular programs during maintenance or modification 1/ work on the main transmitter, necessitating discontinuance of its operation for a period not to exceed five days.

1/ This includes the equipment changes which may be made without authority as set forth elsewhere in the Rules and Regulations and the Standards of Good Engineering Practice or as authorized by the Commission by letter or by construction permit. Where such operation is required for periods in excess of 5 days, request therefore shall be in accordance with section 1.365.

(3) Upon request by a duly authorized representative of the Commission.

(d) The auxiliary transmitter shall be tested at least once each week to determine that it is in proper operating condition and that it is adjusted to the proper frequency, except that in case of operation in accordance with paragraph (c) of this section during any week, the test in that week may be omitted provided the operation under paragraph (c) is satisfactory. A record shall be kept of the time and result of each test operating under paragraph (c).

(e) The auxiliary transmitter shall be equipped with satisfactory control equipment which will enable the maintenance of the frequency emitted by the station within the limits prescribed by these regulations.

(f) The operation power of an auxiliary transmitter may be less than the authorized power of the main transmitter, but in no event shall it be greater than such power.

Alternate main transmitters. - The license of a television broadcast station may be licensed for alternate main transmitters provided that a technical need for such alternate transmitters is shown and that the following conditions are met:

(a) Both transmitters are located at the same place.

(b) Both transmitters shall have the same power rating.

(c) Both transmitters shall meet the construction, installation, operation and performance requirements of the Standards of Good Engineering Practice Concerning Television Broadcast Stations.

Changes in equipment and antenna system. - Licensees of television broadcast stations shall observe the following provisions with regard to changes in equipment and antenna system:

(a) No changes in equipment shall be made:

(1) That would result in the emission of signals outside of the authorized channel.

(2) That would result in the external performance of the transmitter being in disagreement with that prescribed in the Standards of Good Engineering Practice Concerning Television Broadcast Stations.

(b) Specific authority, upon filing formal application (Form FCC No. 333) therefor is required for a change in service area or for any of the following changes:

(1) Changes involving an increase or decrease in the power ratings of the transmitters.

(2) A replacement of the transmitters as a whole.

(3) Change in the location of the transmitting antenna.

(4) Change in antenna system, including transmission line.

(5) Change in location of main studio, if it is proposed to move the main studio to a different city from that specified in the license.

(6) Change in the power delivered to the antenna.

(7) Change in frequency control and/or modulation system.

(c) Specific authority, upon filing informal request therefor, is required for a change in the indicating instruments installed to measure transmitter power output, except by instruments of the same maximum scale reading and accuracy.

(d) Other changes, except as above provided for in this section or in Standards of Good Engineering Practice Concerning Television Broadcast Stations prescribed by the Commission may be made at any time without the authority of the Commission, provided that the Commission shall be promptly notified thereof and such changes shall be shown in the next application for renewal of license.

RULES RELATING TO TECHNICAL OPERATION

Time of operation. - (a) All television broadcast stations will be licensed for unlimited time of operation. Each licensed television station shall maintain a regular program operating schedule of not less than 2 hours in any given broadcast day, and it shall render not less than 28 hours program service per week. In an emergency, however, when due to causes beyond the control of a licensee, it becomes impossible to continue operation, the station may cease operation for a period not to exceed 10 days, provided that the Commission and the Inspector in charge of radio district in which the station is located shall be notified in writing immediately after the emergency develops.

(b) The aural transmitter of a television broadcast station shall not be operated separately from the visual transmitter except for experimental or test purposes, and for purposes incidental to or connected with the operation of the visual transmitter.

(c) Persons desiring to enter into a voluntary sharing arrangement of a television channel may file application therefore with the Commission. Copies of the time-sharing agreement should be filed with the application.

Experimental operation. - Television broadcast stations may conduct technical experimentation directed to the improvement of technical phases of operation and for such purposes may utilize a signal other than the standard television signal subject to the following conditions.

(a) That the licensee complies with the provisions of section 3.661 with regard to the minimum number of hours of transmission with a standard television signal.

(b) That no transmssions are radiated outside of the authorized channel and subject to the condition that no interference is caused to the transmissions of a standard television signal by other television broadcast stations.

(c) No charges either direct or indirect shall be made by the licensee of a television broadcast station for the production or transmission of programs when conducting technical experimentation.

Station inspection. - The licensee of any television broadcast station shall make the station available for inspection by representatives of the Commission at any reasonable hour.

Station license, posting of. - The original of each station license shall be posted in the transmitter room.

Operator requirements. - One or more licensed radio-telephone first class operators shall be on duty at the place where the transmitting apparatus of each station is located and in actual charge thereof whenever it is being operated. The original license (Form FCC No. 759) of each station operator shall be posted at the place where he is on duty. The licensed operator on duty and in charge of a television broadcast transmitter may, at the discretion of the licensee, be employed for other duties or for the operation of another station or stations in accordance with the class of operator's license which he holds and by the rules and regulations governing such stations. However, such duties shall in no way interfere with the operation of the broadcast transmitter.

Operating power; how determined. - The operating power, and the requirements for maintenance thereof, of each television broadcast station shall be determined by the methods prescribed in the Standards of Good Engineering Practice Concerning Television Broadcast Stations.

Modulation. - The percentage of modulation of the aural transmissions shall be maintained as high as possible consistent with good quality of transmission and good broadcast practice and in no case less than 85 per cent nor more than 100 per cent on peaks of frequent recurrence during any selection which normally is transmitted at the highest level of the program under consideration.

Frequency Tolerence. - The operating frequencies of the aural and visual transmitters of a television broadcast station shall be maintained within ,002% of the assigned frequencies.

Inspection of tower lights and associated control equipment. - The license of any television station which has an antenna or antenna supporting structure(s) required to be illuminated persuant to the provisions of section 303 (q) of the Communications Act of 1934 as amended:

(a) Shall make a visual observation of the tower lights at least once each 14 hours to insure that all such lights are functioning properly as required.

(b) Shall report immediately by telephone or telegraph to the nearest Airways Communications Station or office of the Civil Aeronautics Administration any observed failure of tower lights, not corrected within 30 minutes, regardless of the cause of such failure. Further notification by telephone or telegraph shall be given immediately upon resumption of the required illumination.

(c) Shall inspect at intervals of at least once each 3 months all flashing or rotating beacons and automatic lighting control devices to insure that such apparatus is functioning properly as required.

OTHER RULES RELATING TO OPERATION

Logs. - The licensee of each television station shall maintain program and operating logs and shall require entries be made as follows:

(a) In the program log:

(1) An entry of the time each station identification announcement (call letters and location) is made.

(2) An entry briefly describing each program broadcast, such as "music", "drama", "speech", etc., together with the name or title thereof and the sponsor's name, with the time of the beginning and ending of the complete program. If mechanical reproduction, either visual or aural, is used, the entry shall show the exact nature thereof, and the time it is announced as a mechanical reproduction. If a speech is made by a political candidate, the name and political affiliations of such speaker shall be entered.

(3) An entry showing that each sponsored program broadcast has been announced as sponsored, paid for, or furnished by the sponsor.

(4) An entry showing, for each program of network origin, the name of the network originating the program.

(b) In the operating log:

(1) An entry of the time the station begins to supply power to the antenna, and the time it stops.

(2) An entry of the time the program begins and ends.

(3) An entry of each interruption to the carrier wave, its cause, and duration.

(4) An entry of the following each 30 minutes:

(i) Operating constants of last radio stage of the aural transmitter (total plate current and plate voltage.)

(ii) Transmission line current or voltage of both transmitters.

(iii) Frequency monitor reading.

(5) Log of experimental operation during experimental period (if regular operation is maintained during this period, the above logs shall be kept).

(i) A log must be kept of all operation during the experimental period. If the entries required above are not applicable thereto, then the entries shall be made so as to fully describe the operation.

(c) Where an antenna or antenna supporting structure(s) is required to be illuminated, the licensee shall make entries in the radio station log appropriate to the requirements of section 3.669 as follows:

(1) The time the tower lights are turned on and off if manually controlled.

(2) The time the daily visual observation of the tower lights was made.

(3) In the event of any observed failure of a tower light.

(i) Nature of such failure.

(ii) Time the failure was observed.

(iii) Time and nature of the adjustments, repairs or replacements made.

(iv) Airways Communication Station (C.A.A.) notified of the failure of any tower light not corrected within thirty minutes and the time such notice was given.

(v) Time notice was given to the Airways Communication Station (C.A.A.) that the required illumination was resumed.

(4) Upon completion of the periodic inspection required at least once each three months.

(i) The date of the inspection and the condition of all tower lights and associated tower lighting control devices.

(ii) Any adjustments, replacements or repairs made to insure compliance with the lighting requirements.

Logs, retention of. - Logs of Television broadcast stations shall be retained by the licensee for a period of 2 years, However, logs incident to or involved in any claim or complaint of which the licensee has notice shall be retained by the licensee until such claim or complaint has been fully satisfied or until the same has been barred by statute limiting the time for the filing of suits upon such claims.

Logs, by whom kept. - Each log shall be kept by the person or persons competent to do so, having actual knowledge of the facts required, who shall sign the log when starting duty and again when going off duty. The logs shall be made available upon request by an authorized representative of the Commission.

Log form. - The log shall be kept in an orderly manner, in suitable form, and in such detail that the data required for the particular class of station concerned are readily available. Key letters or abbreviations may be used if proper meaning or explanation is contained elswhere in the log.

Correction of logs. - No log or portion thereof shall be erased, obliterated, or willfully destroyed within the period of retention provided by the rules. Any necessary correction may be made only by the person originating the entry who shall strike out the erroneous portion, initial the correction made, and indicate the date of correction.

Rough logs. - Rough logs may be transcribed into condensed form, but in such cases, the original log or memoranda and all portions thereof shall be preserved and made a part of the complete log.

Station identification. - (a) A licensee of a television broadcast station shall make station identification announcement (call letters and location) at the beginning and ending of each time of operation and during the operation on the hour. The announcement at the beginning and ending of each time of operation shall be by both aural and visual means. Other announcements may be by either aural or visual means.

(b) Identification announcements during operation need not be made when to make such announcement would interrupt a single consecutive speech, play, religious service, symphony concert, or any type of production. In such cases the identification announcement shall be made at the first interruption of the entertainment continuity and at the conclusion thereof.

Mechanical reproductions. - (a) Each program which consists in whole or in part of one or more mechanical reproductions, either visual or aural, shall be accompanied by an appropriate announcement to that effect either at the beginning or end of such reproduction or at the beginning or end of the program in which such reproduction is used.

No such announcement shall be required where a mechanical reproduction is used for background music, sound effects, station identification, program identification (theme music of short duration) or identification of sponsorship of the program proper.

(b) The exact form of identifying announcement is not prescribed, but the language shall be clear and in terms commonly used and understood. The licensee shall not attempt affirmatively to create the impression that any program being broadcast by mechanical reproduction consists of live talent.

Sponsored programs, announcement of. - (a) In the case of each program for the broadcasting of which money, services, or other valuable consideration is either directly or indirectly paid or promised to, or charged or received by, any radio broadcast station, the station broadcasting such program shall make, or cause to be made, an appropriate announcement that the program is sponsored, paid for, or furnished either in whole or in part.

(b) In the case of any political program or any program involving the discussion of public controversial issues for which any films, records, transcriptions, talent scripts, or other material or services of any kind are furnished, either directly or indirectly, to a station as an inducement to the broadcasting of such program, an announcement shall be made both at the beginning and conclusion of such program on which such material or services are used that such films, records, transcriptions, talent, scripts, or other material or services have been furnished to such station in connection with the broadcasting of such program; provided, however, that only one such announcement need be made in the case of any program of five minutes duration or less, which announcement may be made either at the beginning or conclusion of the program.

(c) The announcement required by this section shall fully and fairly disclose the true identity of the person or persons by whom or in whose behalf such services or other valuable consideration is received, or by whom the material or services referred to in subsection (b) hereof are furnished. Where an agent or other person contracts or otherwise makes arrangements with a station on behalf of another, and such fact is known to the station, the announcement shall disclose the identity of the person or persons in whose behalf such agent is acting instead of the name of such agent.

(d) In cases of any program, other than a program advertising commercial products or services, which is sponsored, paid for or furnished, either in whole or in part, or for which material or services referred to in subsection (b) hereof are furnished, by a corporation, committee, association or other unincorporated group, the station shall require that a list of the chief executive officers or members of the executive committee or of the board of directors of the corporation, committee, association, or other unincorporated group shall be made available for public inspection at one of the television broadcast stations carrying the program.

(e) In the case of programs advertising commercial products or services, an announcement stating the sponsor's corporate or trade name or the name of the sponsor's product shall be deemed sufficient for the purpose of this section and only one such announcement need be made at any time during the course of the program.

Broadcasts by candidates for public office. - (a) Legally qualified candidate. - A "legally qualified candidate" means any person who has publicly announced that he is a candidate for nomination by a convention of a political party or for nomination or election in a primary, special, or general election, municipal, county, state or national, and who meets the qualifications prescribed by the applicable laws to hold the office for which he is a candidate, so that he may be voted for by the electorate directly or by means of delegates or electors, and who:

(1) has qualified for a place on the ballot; or

(2) is eligible under the applicable law to be voted for by sticker, by writing in his name on the ballot, or other method, and (i) has been duly nominated by a political party which is commonly known and regarded as such, or (ii) makes a substantial showing that he is a bona fide candidate for nomination or office, as the case may be.

(b) General requirements. - No station licensee is required to permit the use of its facilities by any legally qualified candidate for public office, but if any licensee shall permit any such candidate to use its facilities, it shall afford equal opportunities to all other such candidates for that office to use such facilities, provided, that such licensee shall have no power of censorship over the material broadcast by any such candidate.

(c) Rates and practices. - The rates, if any, charged all such candidates for the same office shall be uniform and shall not be rebated by any means, directly or indirectly. No licensee shall make any discrimimation in charges, practices, regulations, facilities, or services for or in connection with any service rendered persuant to these rules, or make or give any preference to any candidate for public office or subject any such candidate to any prejudice or disadvantage; nor shall any licensee make any contract or other agreement which shall have the effect of permitting any legally qualified candidate for any public office to broadcast to the exclusion of other legally qualified candidates for the same public office.

(d) Inspection of records. - Every licensee shall keep and permit public inspection of a complete record of all requests for broadcast time made by or on behalf of candidates for public office, together with an appropriate notation showing the disposition made by the licensee of such requests, and the charges made, if any, if request is granted.

Rebroadcast. - (a) The term "rebroadcast" means reception by radio of the program 1/ of a radio station, and the simultaneous or subsequent retransmission of such program by a broadcast station. The broadcasting of a program relayed by a relay broadcast station or studio transmitter link is not considered a rebroadcast.

(b) The licensee of a television broadcast station may, without further authority of the Commission, rebroadcast the program of a United States Television broadcast station, provided the Commission is notified of the call letters of each station rebroadcast and the licensee certifies that express authority has been received from the licensee of the station originating the program. 2/

1/ As used in this section, program includes any complete program or part thereof.

2/ The notice and certification of consent shall be given within three (3) days of any single re-broadcast, but in case of the regular practice of rebroadcasting certain programs of a television broadcast station several times during a license period, notice and certification of consent shall be given for the ensuing license period with the application for renewal of license, or at the beginning of such rebroadcast practice if begun during a license period.

(c) No licensee of a television broadcast station shall rebroadcast the program of any United States radio station not designated in (b) above without written authority having first been obtained from the Commission upon application (informal) accompanied by written consent or certification of consent of the licensee of the station originating the program. 1/

RULES GOVERNING F-M BROADCAST STATIONS

Classification of F-M Stations and Allocation of Frequencies

Numerical designation of F-M channels. For convenience, the frequencies available for F-M broadcasting (including those assigned to noncommercial education broadcasting) are given numerical designations which are shown in the table below:

Frequency (mc.)	Channel No.	Frequency (mc.)	Channel No.	Frequency (mc.)	Channel No.	Frequency (mc.)	Channel No.
88.1	201	93.1	226	98.1	251	103.1	276
88.3	202	93.3	227	98.3	252	103.3	277
88.5	203	93.5	228	98.5	253	103.5	278
88.7	204	93.7	229	98.7	254	103.7	279
88.9	205	93.9	230	98.9	255	103.9	280
89.1	206	94.1	231	99.1	256	104.1	281
89.3	207	94.3	232	99.3	257	104.3	282
89.5	208	94.5	233	99.5	258	104.5	283
89.7	209	94.7	234	99.7	259	104.7	284
89.9	210	94.9	235	99.9	260	104.9	285
90.1	211	95.1	236	100.1	261	105.1	286
90.3	212	95.3	237	100.3	262	105.3	287
90.5	213	95.5	238	100.5	263	105.5	288
90.7	214	95.7	239	100.7	264	105.7	289
90.9	215	95.9	240	100.9	265	105.9	290
91.1	216	96.1	241	101.1	266	106.1	291
91.3	217	96.3	242	101.3	267	106.3	292
91.5	218	96.5	243	101.5	268	106.5	293
91.7	219	96.7	244	101.7	269	106.7	294
91.9	220	96.9	245	101.9	270	106.9	295
92.1	221	97.1	246	102.1	271	107.1	296
92.3	222	97.3	247	102.3	272	107.3	297
92.5	223	97.5	248	102.5	273	107.5	298
92.7	224	97.7	249	102.7	274	107.7	299
92.9	225	97.9	250	102.9	275	107.9	300

1/ By order No. 82, dated and effective June 24, 1941, until further order of the Commission, section 3.691 (d) is suspended only insofar as it requires prior written authority of the Commission for the rebroadcasting of programs originated for that express purpose by United States Government radio stations.

Areas of the United States. For the purpose of allocation, the United States is divided into two areas. The first area -- Area I -- includes southern New Hampshire; all of Massachusetts, Rhode Island and Connecticut; southeastern New York as far north as Albany-Troy-Schenectady; all of New Jersey, Delaware, and the District of Columbia; Maryland as far west as Hagerstown; and eastern Pennsylvania as far west as Harrisburg. 1/ The second area -- Area II - comprehends the remainder of the United States not included in Area I.

Community stations. (a) Community stations are limited to a maximum effective radiated power of 250 watts and a maximum antenna height of 250 feet over the average height of the terrain 10 miles from the transmitter. Upon proper showing that an antenna height in excess of 250 feet is necessary, authorization will be issued for such higher antenna but the Commission may, in such cases, require a reduction in radiated power. A minimum separation of 50 miles will be provided in the case of community stations on the same channel and a minimum of 35 miles on adjacent channels.

(b) In area I, 20 channels beginning with 104.1 mc. and ending with 107.9 mc. (channels 281 through 300) are allocated for community stations. All of these 20 channels are available in any community which is not the principal city of a metropolitan district. Ten of these channels are also available for assignment in principal cities of metropolitan districts which have fewer than six metropolitan stations. 2/

(c) In Area II, 10 channels beginning with 104.1 mc. and ending with 105.9 mc. (channels 281 through 290 are available for community stations and may be used in any community which is not the principal city of a metropolitan district. 3/

(d) The main studio of a community station shall be located in the city served and the transmitter shall be located as near the center of the city as practicable.

Metropolitan Stations. (a) In area I, metropolitan stations are limited to a maximum of 20 kw. effective radiated power with a nondirectional antenna having a height of 500 feet, as determined by the methods prescribed in the Standards of Good Engineering Practice Concerning F-M broadcast stations. Where higher antenna heights are available, they should be used but in such cases the Commission will authorize less than 20 kw. effected radiated power so that the coverage (within the 1,000 uv/m contour) shall be substantially similar to that which would

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1/ In some of the territory contiguous to Area I, the demand for frequencies may, in the future, exceed the supply and when it does this region will be added to Area I. Until then, careful study and consideration to insure an equitable distribution of facilities throughout the region. This region includes the remainder of Maryland, Pennsylvania and New York (except the northeastern corner) not included in Area I; the northern half of West Virginia; all of Ohio and Indiana; southern Michigan as far north as Saginaw; eastern Illinois as far west as Rockford-Decatur; and southeastern Wisconsin as far north as Sheboygan.

2/ For the time being, until more F-M stations are authorized, the Commission will not authorize community stations in principal cities of metropolitan districts in Area I having four or more A-M stations.

3/ The 10 frequencies from 106.1 mc. to 107.9 mc. which are available for community stations in Area I but not in Area II will be assigned in Area II in the future in accordance with the needs of the area as shown by future developments. In the meantime they will be available for facsimile.

be provided by 20 kw. effective radiated power and a 500 foot antenna. Where the only antenna height available is less than 500 feet, the Commission may authorize its use but will not permit an increase in radiated power in excess of 20 kw. In Area I, the service area of metropolitan stations will not be protested beyond the 1,000 uv/m contour and such stations will be located in such a manner as to insure, insofar as possible, a maximum of F-M service to all listeners, whether urban or rual.

(b) Metropolitan stations in Area II are designed primarily to render service to a single metropolitan district or a principal city, and to rural areas surrounding such metropolitan district or principal city. The Commission will designate service areas for metropolitan stations in Area II and will authorize appropriate power and antenna height to cover the designated area in accordance with the Standards of Good Engineering Practice Concerning F-M broadcast stations. Upon proper showing, changes will be made in these service areas. 1/ Metropolitan stations will not be required to serve the entire service area designated by the Commission but no application will be granted for a metropolitan station unless it is proposed to serve an area substantially greater than could be served by a community station.

(c) Sixty frequencies are available for metropolitan stations in Areas I and II. These frequencies begin at 92.1 mc. and end at 103.9 mc. (channels 221 through 280).

(d) The main studio of a metropolitan station shall be located within its 5,000 uv/m contour. However, upon a special showing of need, the Commission may authorize the main studio to be located beyond the 5,000 uv/m contour but not beyond the 1,000 uv/m contour. The transmitter shall be so located as to provide maximum service both to the city where the main studio is located and to the surrounding rural area.

Rural Stations. (a) Rural stations are designed primarily to furnish service to rural listeners. The service area of rural stations may include the service areas designated by the Commission for metropolitan stations upon a showing to the Commission that the additional area which the rural station will serve is predominantly rural in character. As a guide, the Commission will consider that the additional area beyond the service area of a metropolitan station which is proposed to be served, is predominantly rural in character if at least 50 percent of the population proposed to be added within the 50 uv/m contour live in rural areas or in communities smaller than 10,000. 2/ Exceptions to this rule will be permitted where a showing is made to the Commission that due to conditions of terrain or local factors, more extended service to unserved rural areas is possible by licensing rural stations to serve an area which does not meet the above requirements than would otherwise be possible.

1/ In determining service areas for particular communities, the Commission will give consideration to population distribution, terrain, trade areas, economics and other pertinent factors, and applicants for metropolitan stations in Area II should include in their applications a showing as to the service area the Commission should designate for the city in question. There are several current and recognized authorities on retail trading areas or consumer trading areas from which the applicant may prepare its showing and to which the Commission will give consideration in making its determination. Among these recognized authorities are the following: J. Walter Thompson (Retail Shopping Areas), Hearst Magazines, Inc. (Consumer Trading Areas), Rand McNally Map Co. (Trading Areas), and Hagastrom Map Co. (Four Color Retail Trading Area Map).

2/ In making this computiation, cities with populations in excess of 10,000 should be excluded if the signal in such cities is less than 500 uv/m.

(b) Rural stations will not be licensed in Area I as presently defined. If in the future it becomes necessary to extend Area I by including part or all of the region set forth in footnote 1 in the section entitled Areas of the United States, consideration will be given at that time to the question whether rural stations should be licensed in this region.

(c) The 60 channels available for metropolitan stations are also available for rural stations.

(d) The main studio of a rural station shall be located within its 1,000 uv/m contour. However, upon a special showing of need, the Commission may authorize the main studio to be located beyond the 1,000 uv/m contour but not beyond the 50 uv/m contour.

Rules Governing Administrative Procedure

Application for F-M station. Each applicant for a construction permit for a new F-M broadcast station, change in facilities of any existing F-M broadcast station, or F-M station license or modification of license shall file with the Commission in Washington, D.C., three copies of applications on the appropriate form designated by the Commission and a like number of exhibts and other papers incorporated therein and made a part thereof. Only the original copy need be sworn to. If the application is for a construction permit for a new F-M station, Form FCC No. 319 should be filed; for an F-M license, Form FCC No. 320 should be filed; and for modification of an F-M license or for change in facilities of an existing F-M station, Form FCC No. 322 should be filed.

Full disclosures. Each application shall contain full and complete disclosures with regard to the real party or parties in interest, and their legal, technical, financial, and other qualifications, and as to all matters and things required to be disclosed by the application forms.

Installation or removal of apparatus. Applications for construction permit or modification thereof, involving removal of existing transmitting apparatus and/or installation of new transmitting apparatus, shall be filed at least 60 days prior to the contemplated removal and/or installation.

Period of construction. Each construction permit will specify a maximum of 60 days from the date of granting threof as the time within which construction of the station shall begin, and a maximum of six months thereafter as the time within which construction shall be completed and the station ready for operation, unless otherwise determined by the Commission upon proper showing in any particular case.

Forfeiture of construction permits: Extension of time. (a) A construction permit shall be automatically forfeited if the station is not ready for operation within the time specified therein or within such further time as the Commission may have allowed for completion, and a notation of the forfeiture of any construction permit under this provision will be placed in the records of the Commission as of the expiration date.

(b) Any application 1/ for extension of time within which to construct a station shall be filed at least 30 days prior to the expiration date of such permit if the facts supporting such application for extension are known to the applicant in time to permit such filing. In other cases such applications will be accepted upon a showing satisfactory to the Commission of sufficient reasons for filing within less than 30 days prior to the expiration date. Such applications will be granted upon a specific and detailed showing that the failure to complete was due to causes not under the control of the grantee, or upon a specific and detailed showing of other matters sufficient to justify the extension.

1/ Form FCC No. 701.

Equipment tests. (a) Upon completion of construction of an F-M station in exact accordance with the terms of the construction permit, the technical provisions of the application thereof and the rules and regulations and Standards of Good Engineering Practice governing F-M stations and prior to filing of an application for license, the permitee is authorized to test the equipment for a period not to exceed 90 days: Provided, that the inspector-in-charge of the district in which the station is located and the Commission are notified two days in advance of the beginning of tests.

(b) The Commission may notify the permitee to conduct no tests or may cancel, suspend, or change the date of beginning for the period of such tests as and when such action may appear to be in the public interest, convenience, and necessity.

(c) Within the 90-day period prescribed by this section for equipment tests, field intensity measurements in accordance with the methods prescribed in the Standards of Good Engineering Practice concerning F-M broadcasting shall be submitted to the Commission. The Commission may grant extensions of time upon showing of reasonable need thereof. 1/ The proof of performance specified in this subsection shall be made by metropolitan and rural stations only and need not be made by community stations.

Program tests. (a) When construction and equipment tests are completed in exact accordance with the terms of the construction permit, the technical provisions of the application therefor, and the rules and regulations and Standards of Good Engineering Practice governing F-M stations, and after an application for station license has been filed with the Commission showing the transmitter to be in satisfactory operating condition, the permittee is authorized to conduct program tests in exact accordance with the terms of the construction permit for a period not to exceed 30 days: Provided, that the inspector-in-charge of the district in which the station is located and the Commission are notifed two days in advance of the beginning of such tests.

(b) The Commission reserves the right to cancel such tests or suspend, or change the date of beginning for the period of such tests as and when such action may appear to be in the public interest, convenience, and necessity by notifying the permittee.

(c) The authorization for tests embodied in this section or section entitled Equipment Tests shall not be construed as constituting a license to operate but as a necessary part of the construction.

Normal license period. All F-M broadcast station licenses will be issued so as to expire at the hour of 3 A.M. E.S.T. and will be issued for a normal license period of 1 year.

License, simultaneous modification and renewal. When an application is granted by the Commission necessitating the issuance of a modified license less than 60 days prior to the expiration date of the license sought to be modified, and an application for renewal of said license is granted subsequent or prior thereto (but within 30 days of expiration of the present license) the modified license as well as the renewal license shall be issued to conform to the combined action of the Commission.

Renewal of license. (a) Unless otherwise directed by the Commission, each application for renewal of an F-M license shall be filed at least 60 days prior to the expiration date of the license sought to be renewed (Form FCC No. 311). No application for renewal of license of an F-M broadcast station will be considered unless there is on file with the Commission, the information currently required by sections 1.301-1.304, reference to which by date and file number shall be included in the application.

1/ Until further notice, the Commission will grant F-M licenses before proof of performance is submitted. In such cases, proof of performance shall be submitted within 1 year after the license has been issued or within such extension of time as the Commission may for good cause grant.

(b) Whenever the Commission regards an application for a renewal of an F-M license as essential to the proper conduct of a hearing or investigation, and specifically directs that it be filed by a certain date, such application shall be filed within the time thus specified. If the licensee fails to file such application within the prescribed time, the hearing or investigation shall proceed as if such renewal application had been received.

Temporary extension of station licenses. Where there is pending before the Commission any application, investigation, or proceeding which, after hearing, might lead to or make necessary the modification of, revocation of, or the refusal to renew an existing F-M license, the Commission may, in its discretion, grant a temporary extension of such license: Provided, however, that no such temporary extension shall be construed as a finding by the Commission that the operation of any radio station thereunder will serve public interest, convenience, and necessity beyond the express terms of such temporary extension of license: And provided further, that such temporary extension of license will in no wise affect or limit the action of the Commission to any pending application or proceeding.

Repetitious applications. (a) Where an applicant has been afforded an opportunity to be heard with respect to a particular application for a new F-M broadcast station, or for change of existing service or facilities, and the Commission has, after hearing or default, denied the application or dismissed it with prejudice, the Commission will not consider another application for a station of the same class to serve in whole or in part the same area, by the same applicant or by his successor or assignee, or on behalf of or for the benefit of the original parties in interest, until after the lapse of 12 months from the effective date of the Commission's order.

(b) Where an appeal has been taken from the action of the Commission in denying a particular application, another application for the same class of broadcast station and for the same area, in whole or in part, filed by the same applicant or by his successor or assignee, or on behalf or for the benefit of the original parties in interest, will not be considered until the final disposition of such appeal.

Assignment or transfer of control. (a) Voluntary. Application for consent to voluntary assignment of an F-M construction permit or license or for consent to voluntary transfer of control of a corporation holding an F-M construction permit or license shall be filed with the Commission on form FCC No. 314 (assignment of license) and Form FCC No. 315 (transfer of control) at least 60 days prior to the contemplated effective date of assignment or transfer of control.

(b) Involuntary. In the event of the death or legal disability of a permitte or licensee, or a member of a partnership, or a person directly or indirectly in control of a corporation which is a permittee or licensee:

(1) The commission shall be notified in writing promptly of the occurrence of such death or legal disability, and

(2) Within 30 days after the occurrence of such death or legal disability, application on Form FCC No. 314 or 315 shall be filed for consent to involuntary assignment of such F-M permit or license or for involuntary transfer of control of such corporation to a person or entity legally qualified to succeed to the foregoing interests under the laws of the place having jurisdiction over the estate involved.

Rules Relating to Licensing Policies

Exclusive affiliation of station. No license shall be granted to an F-M broadcast station having any contract, arrangement, or understanding, express or implied, with a network organization 1/

1/ The term "network organization" as used herein includes national and regional network organizations. See Chapter VII, J, or Report on Chain Broadcasting.

under which the station is prevented or hindered from, or penalized for, broadcasting the programs of any other network organization.

Territorial exclusivity. No license shall be granted to an F-M broadcast station having any contract, arrangement, or understanding, express or implied, with a network organization which prevents or hinders another broadcast station serving substantially the same area from broadcasting the network's programs not taken by the former station, or which prevents or hinders another broadcast station serving a substantially different area from broadcasting any program of the network organization. This regulation shall not be construed to prohibit any contract, arrangement or understanding between a station and a network organization persuant to which the station is granted the first call in its primary service area upon the programs of the network organization.

Terms of affiliation. No license shall be granted to an F-M broadcast station having any contract, arrangement, or understanding, express or implied, with a network organization which provides, by original terms, provisions for renewal, or otherwise for the affiliation of the station with the network organization for a period longer than 2 years: Provided, That a contract, arrangement, or understanding for a period up to 2 years, may be entered into within 6 months prior to the commencement of such period.

Option time. No license shall be granted to an F-M broadcast station which options 1/ for network programs any time subject to call on less than fifty-six day's notice, or more time than a total of three hours 2/ within each of four segments of the broadcast day, as herein described. The broadcast day is divided into four segments as follows: 8 A.M. to 1 P.M.; 1 P.M. to 6 P.M.; 6 P.M. to 11 P.M.; 11 P.M. to 8 A.M. 3/. Such options may not be exclusive as against other network organizations and may not prevent, or hinder the station from optioning or selling any or all of the time covered by the option, or other time, to other network organizations.

Right to reject programs. No license shall be granted to an F-M broadcast station having any contract, arrangement, or understanding, express or implied, with a network organization which (a) with respect to programs offered pursuant to an affilitation contract, prevents or hinders the station from rejecting or refusing network programs which the station reasonably believes to be unsatisfactory or unsuitable; or which (b) with respect to network programs so offered or already contracted for, prevents the station from rejecting or refusing any program which, in its opinion, is contrary to the public interest, or from substituting a program of of outstanding local or national importance.

1/ As used in this section, an option is any contract, arrangement, or understanding, express or implied between a station and a network organization which prevents or hinders the station from scheduling programs before the network agrees to utilize the time during which such programs are secheduled, or which requires the station to clear time already scheduled when the network seeks to utilize the time.

2/ All time options permitted under this section must be specified clock hours, expressed in terms of any time system set forth in the contract agreed upon by the station and network organization. Shifts from daylight saving to standard time or vice versa may or may not shift the specified hours correspondingly as agreed by the station and network organization.

3/ These segments are to be determined for each station in terms of local time at the location of the station but may remain constant throughout the year regardless of shifts from standard to daylight saving time or vice versa.

Network ownership of stations. No license shall be granted to a network organization, or to any person directly or indirectly controlled by or under common control 1/ of a network organization, for an F-M broadcast station in any locality where the existing F-M broadcast stations are so few or of such unequal desirability (in terms of coverage, power, frequency, or other related matters) that competition would be substantially restrained by such licensing.

Dual network operation. No license shall be issued to an F-M broadcast station affiliated with a network organization which maintains more than one network of F-M broadcast stations: Provided, That this regulation shall not be applicable if such networks are not operated simultaneously, or if there is no substantial overlap in the territory served by the group of stations comprising each such network.

Use of common antenna site. No F-M license or renewal of an F-M license will be granted to any person who owns, leases, or controls a particular site which is peculiarly suitable for F-M broadcasting in a particular area and (1) which is not available for use by other F-M licensees; and (2) no other comparable site is available in the area; and (3) where the exclusive use of such site by the applicant or licensee would unduly limit the number of F-M stations that can be authorized in a particular area or would unduly restrict competition among F-M stations.

Multiple ownership. (a) No person (including all persons under common control)2/ shall, directly or indirectly, own, operate or control more than one F-M broadcast station owned, operated, or controlled by such person.

(b) No person (including all persons under common control) shall, directly or indirectly, own, operate, or control more than one F-M broadcast station, except upon a showing (1) that such ownership, operation, or control would foster competition among F-M broadcast stations or provide an F-M broadcasting service distinct and separate from existing services, and (2) that such ownership, operation, or control would not result in the concentration of control of F-M broadcasting facilities in a manner inconsistent with public interest, convenience, or necessity: Provided, however, That the Commission will consider ownership, operation, or control of more than six F-M broadcast stations to constitute the concentration of control of F-M broadcasting facilities in a manner inconsistent with public interest, convenience, or necessity.

Rules Relating to Equipment

Transmitter power. The rated power and operating power range of transmitters shall be in accordance with the Standards of Good Engineering Practice concerning F-M broadcast stations.

Frequency monitor. The licensee of each F-M broadcast station shall have in operation at the transmitter an approved frequency monitor independent of the frequency control of the transmitter. For detailed requirements thereof see Standards of Good Engineering Practice concerning F-M broadcast stations.

Required transmitter performance. The construction, installation, operation, and performance of the F-M broadcast transmitter system shall be in accordance with the Standards of Good Engineering Practice concerning F-M broadcast stations.

1/ The word "control" as used herein, is not limited to full control but includes such a measure of control as would substantially affect the availability of the station to other networks.

2/ The word "control" as used herein is not limited to majority stock ownership, but includes actual working control in whatever manner exercised.

Auxiliary transmitter. Upon showing that a need exists for the use of an auxiliary transmitter in addition to the regular transmitter of a broadcast station, a license therefore may be issued provided that:

(a) An auxiliary transmitter may be installed either at the same location as the main transmitter or at another location.

(b) A licensed operator shall be in control whenever an auxiliary transmitter is placed in operation.

(c) The auxiliary transmitter shall be maintained so that it may be put into immediate operation at any time for the following purposes:

(1) The transmission of the regular programs upon failure of the main transmitter.

(2) The transmission of regular programs during maintenance or modification 1/ work on the main transmitter, necessitating discontinuance of its operation for a period not to exceed 5 days.

(3) Upon request by a duly authorized representative of the Commission.

(d) The auxiliary transmitter shall be tested at least once each week to determine that it is in proper operating condition and that it is adjusted to the proper frequency, except that in case of operation in accordance with paragraph (c) of this section during any week, the test in that week may be omitted provided the operation under paragraph (c) is satisfactory. A record shall be kept of the time and result of each test operating under paragraph (c). Tests shall be conducted only between midnight and 6 A.M., local standard time.

(e) The auxiliary transmitter shall be equipped with satisfactory control equipment which will enable the maintenance of the frequency emitted by the station within the limits prescribed by these regulations.

(f) The operating power of an auxiliary transmitter may be less than the authorized power of the main transmitter, but in no event shall it be greater than such power.

Alternate main transmitters. The licensee of an F-M broadcast station may be licensed for alternate main transmitters provided that a technical need 2/ for such alternate transmitters is shown and that the following conditions are met:

(a) Both transmitters are located at the same place.

(b) Both transmitters shall have the same power rating.

(c) Both transmitters shall meet the construction, installation, operation, and performance requirements of the Standards of Good Engineering Practice concerning F-M broadcast stations.

1/ This includes the equipment changes which may be made without authority as set forth elsewhere in the Rules and Regulations and the Standards of Good Engineering Practice or as authorized by the Commission by letter or by construction permit. Where such operation is required for periods in excess of 5 days, request therefore shall be in accordance with section 1.365.

2/ Such as licensees maintaining 24-hour schedule and needing alternate operation for maintenance, or where developmental work requires alternate operation.

Changes in equipment and antenna system. Licensees of F-M broadcast stations shall observe the following provisions with regard to changes in equipment and antenna system:

(a) No changes in equipment shall be made:

(1) That would result in the emission of signals outside of the authorized channel.

(2) That would result in the external performance of the transmitter being in disagreement with that prescribed in the Standards of Good Engineering Practice concerning F-M broadcast stations.

(b) Specific authority, upon filing formal application (Form FCC No. 322) therefor, is required for a change in service area or for any of the following changes:

(1) Changes involving an increase or decrease in the power rating of the transmitter.

(2) A replacement of the transmitter as a whole.

(3) Change in the location of the transmitting antenna.

(4) Change in antenna system, including transmission line.

(5) Change in location of main studio, if it is proposed to move the main studio to a different city from that specified in the license.

(6) Change in power delivered to the antenna.

(7) Change in frequency control and/or modulation system.

(c) Specific authority, upon filing informal request therefor, is required for a change in the indicating instruments installed to measure transmitter power output, except by instruments of the same maximum scale reading and accuracy.

(d) Other changes, except as above provided for in this section or in Standards of Good Engineering Practice concerning F-M broadcast stations prescribed by the Commission may be made at any time without the authority of the Commission, provided that the Commission shall be promptly notified thereof and such changes shall be shown in the next application for renewal of license.

Rules Relating to Technical Operation

Time of operation. All F-M broadcast stations will be licensed for unlimited time operation. Until further notice a minimum of 6 hours per day of operation will be required, which shall consist of 3 hours during the period 6 A.M. to 6 P.M., local standard time, and 3 hours during the period 6 P.M. to midnight, local standard time. In an emergency, however, when due to causes beyond the control of a licensee, it becomes impossible to continue operation, the station may cease operation for a period not to exceed 10 days, provided that the Commission and the inspector in-charge of the radio district in which the station is located shall be notified in writing immediately after the emergency develops.

Experimental operation. The period between 12 midnight and 6 A.M., local standard time, may be used for experimental purposes in testing and maintaining apparatus by the licensee of any F-M broadcast station on its assigned frequency and not in excess of its authorized power, without specific authorization from the Commission.

Station inspection. The licensee of any F-M radio station shall make the station available for inspection by representatives of the Commission at any reasonable hour.

Station license, posting of The original of each station license shall be posted in the transmitter room.

Operator requirements. One or more licensed radio telephone first-class operators shall be on duty at the place where the transmitting apparatus of each station is located and in actual charge thereof whenever it is being operated. The original license (Form FCC No. 759) of each station operator shall be posted at the place where he is on duty. The licensed operator on duty and in charge of an F-M broadcast transmitter may, at the discretion of the licensee, be employed for other duties or for the operation of another station or stations in accordance with the class of operator's license which he holds and by the rules and regulations governing such stations. However, such duties shall in no wise interfere with the operation of the broadcast transmitter.

Facsimile broadcasting and multiplex transmission. Transmission of simplex facsimile in F-M channels in accordcance with the Commission's Standards of Good Engineering Practice on facsimile may be permitted, upon application to the Commission, during hours not required to be devoted to F-M aural broadcasting. The Commission may grant experimental authority to an F-M station for the multiplex transmission of facsimile or other signals and aural broadcast programs, provided that the transmission of facsimile or other signals is incidental to the aural broadcast, does not reduce the quality of the aural program, and that a filter or other additional equipment is not required for receivers not equipped to receive facsimile or other signals.

Operating power: how determined. The operating power, and the requirements for maintenance thereof, of each F-M broadcast station shall be determined by the methods prescribed in the Standards of Good Engineering Practice covering F-M broadcast stations.

Modulation. The percentage of modulation of all stations shall be maintained as high as possible consistent with good quality of transmission and good broadcast practice and in no case less than 85 per cent nor more than 100 per cent on peaks of frequent recurrence during any selection which normally is transmitted at the highest level of the program under consideration.

Frequency tolerance. The center frequency of each F-M broadcast station shall be maintained within 2,000 cycles of the assigned center frequency.

Inspection of tower lights and associated control equipment. The licensee of any F-M station which has an antenna or antenna supporting structure (s) required to be illuminated pursuant to the provisions of section 303 (q) of the Communications Act of 1934, as ammended:

(a) Shall make a visual observation of the tower lights at least once each 24 hours to insure that all such lights are functioning properly as required.

(b) Shall report immediately by telephone or telegraph to the nearest Airways Communication Station or office of the Civil Aeronautics Administration any observed failure of the tower lights, not corrected within 30 minutes, regardless of the cause of such failure. Further notification by telephone or telegraph shall be given immediately upon resumption of the required illumination.

(c) Shall inspect at intervals of at least once each 3 months all flashing or rotating beacons and automatic lighting control devices to insure that such apparatus is functioning properly as required.

Logs. The licensee of each F-M station shall maintain program and operating logs and shall require entries to be made as follows:

(a) In the program log:

(1) An entry of the time each station identification announcement (call letters and location) is made.

(2) An entry briefly describing each program broadcast, such as "music", "drama", "speech", etc., together with the name or title thereof and the sponsor's name, with the time of the beginning and ending of the complete program. If a mechanical record is used, the entry shall show the exact nature thereof, such as "record", "transcription", etc., and the time it is announced as a mechanical reproduction. If a speech is made by a political candidate, the name and political affiliations of such speaker shall be entered.

(3) An entry showing that each sponsored program broadcast has been announced as sponsored, paid for, or furnished by the sponsor.

(4) An entry showing, for each program of network origin, the name of the network originating the program.

(b) In the operating log:

(1) An entry of the time the station begins to supply power to the antenna, and the time it stops.

(2) An entry of the time the program begins and ends.

(3) An entry of each interruption to the carrier wave, its cause, and duration.

(4) An entry of the following each 30 minutes:

(i) Operating constants of last radio stage (total plate current and plate voltage).
(ii) Transmission line current or voltage.
(iii) Frequency monitor reading.

(5) Log of experimental operation during experimental period (if regular operation is maintained during this period, the above logs shall be kept).

(i) A log must be kept of all operation during the experimental period. If the entries required above are not applicable thereto, then the entries shall be made so as to fully describe the operation.

(c) Where an antenna or antenna supporting structure(s) is required to be illuminated the licensee shall make entries in the radio station log as follows:

(1) The time the tower lights are turned on and off if manually controlled.

(2) The time the daily visual observation of the tower lights was made.

(3) In the event of any observed failure of a tower light,

(i) Nature of such failure.
(ii) Time the failure was observed
(iii) Time and nature of the adjustments, repairs or replacements made.
(iv) Airways Communication Station (C.A.A.) notified of the failure of any tower light nor corrected within 30 minutes and the time such notice was given.
(v) Time notice was given to the Airways Communication Station (C.A.A.) that the required illumination was resumed.

(4) Upon completion of the periodic inspection required at least once each 3 months.

(i) The date of the inspection and the condition of all tower lights and associated tower lightning control devices.
(ii) Any adjustments, replacements or repairs made to insure compliance with the lighting requirements.

Logs, retention of. Logs of F-M stations shall be retained by the licensee for a period of two years. However, logs incident to or involved in any claim or complaint of which the licensee has notice shall be retained by the licensee until such claim or complaint has been fully satisfied or until the same has been barred by the statute limiting the time for the filing of suits upon such claims.

Logs, by whom kept. Each log shall be kept by the person or persons competent to do so, having actual knowledge of the facts required, who shall sign the log when starting duty and again when going off duty. The logs shall be made available upon request by an authorized representative of the Commission.

Log form. The log shall be kept in an orderly manner, in suitable form, and in such detail that the data required for the particular class of station concerned are readily available. Key letters or abbreviations may be used if proper meaning or explanation is contained elsewhere in the log.

Correction of logs. No log or portion thereof shall be erased, obliterated, or willfully destroyed within the period of retention provided by the rules. Any necessary correction may be made only by the person originating the entry who shall strike out the erroneous portion, initial the correction made, and indicate the date of correction.

Rough logs. Rough logs may be transcribed into condensed form, but in such case the original log or memoranda and all portions thereof shall be preserved and made a part of the complete log.

Station identification. (a) A licensee of an F-M broadcast station shall make station identification announcement (call letters and location) at the beginning and ending of each time of operation and during operation, (1) on the hour and (2) either on the half hour or at the quarter hour following the hour and at the quarter hour preceding the next hour.

(b) Such identification announcement need not be made on the hour when to make such announcement would interrupt a single consecutive speech, play, religious service, symphony concert, or operatic production of longer duration than 30 minutes. In such cases the identification announcement shall be made at the beginning of the program, at the first interruption of the entertainment continuity, and at the conclusion of the program.

(c) Such identification announcement need not be made on the half hour or quarter hours when to make such announcement would interrupt a single consecutive speech, play, religious service, symphony concert, or operatic production. In such cases an identification announcement shall be made at the first interruption of the entertainment continuity and at the conclusion of the program, Provided, That an announcement within 5 minutes of the time specified in subdivision (2) of paragraph (a) of this section will satisfy the requirements of identification announcements.

(d) In the case of variety show programs, baseball game programs, or similar programs of longer duration than 30 minutes, the identification announcement shall be made within 5 minutes of the hour and of the times specified in subdivision (2) of paragraph (a) of this section.

(e) In the case of all other programs, the identification announcement shall be made within 2 minutes of the hour and of the times specified in subdivision (2) of paragraph (a) of this section.

(f) In making the identification announcement, the call letters shall be given only on the channel of the station identified thereby.

Mechanical records. Each program broadcast which consists in whole or in part of one or more mechanical reproductions shall be announced in the manner and to the extent set out below.

(a) Each such program of longer duration than 30 minutes, consisting in whole or in part of one or more mechanical reproductions, shall be identified by appropriate announcement at the beginning of the program, at each 30-minute interval and at the conclusion of the program; Provided, however, That the identifying announcement at each 30-minute interval is not required in the case of a mechanical reproduction consisting of a continuous uninterrupted speech, play, religious service, symphony concert, or operatic production of longer than 30 minutes.

(b) Each program of a longer duration than 5 minutes and not in excess of 30 minutes, consisting in whole or in part of one or more mechanical reproductions, shall be identified by an appropriate announcement at the beginning and end of the program.

(c) Each program of 5 minutes or less, consisting in whole or in part of mechanical reproductions, shall be identified by appropriate announcement immediately preceding the use thereof.

(d) In case a mechanical reproduction is used for background music, sound effects, station identification, program identification (theme music of short duration) or identification of the sponsorship of the program proper, no announcement of the mechanical reproduction is required.

(e) The exact form of identifying announcement is not prescribed, but the language shall be clear and in terms commonly used and understood. A licensee shall not attempt affirmatively to create the impression that any program being broadcast by mechanical reproduction consists of live talent.

Sponsored programs, announcement of. (a) In the case of each program for the broadcasting of which money, services, or other valuable consideration is either directly or indirectly paid or promised to, or charged or received by, any radio broadcast station, the station broadcasting such program shall make, or cause to be made an appropriate announcement that the program is sponsored, paid for, or furnished, either in whole or in part.

(b) In the case of any political program or any program involving the discussion of public controversial issues for which any records, transcriptions, talent, scripts, or other material or services of any kind are furnished, either directly or indirectly, to a station as an inducement to the broadcasting of such program, an announcement shall be made both at the beginning or conclusion of such program on which such material or services are used that records, transcriptions, talent scripts, or other material or services have been furnished to such station in connection with the broadcasting of such program: Provided, however, That only one such program of 5 minutes' duration or less, which announcement may be made either at the beginning or conclusion of the program.

(c) The announcement required by this section shall fully and fairly disclose the true identity of the person or persons by whom or in whose behalf such payment is made or promised, or from whom or in whose behalf such services or other valuable consideration is received, or by whom the material or services referred to in subsection (b) hereof are furnished. Where an agent or other person contracts or otherwise makes arrangements with a station on behalf of another, and such fact is known to the station, the announcement shall disclose the identity of the person or persons in whose behalf such agent is acting instead of the name of such agent.

(d) In the case of any program, other than a program advertising commercial products or services, which is sponsored, paid for or furnished, either in whole or in part, or for which material or services referred to in subsection (b) hereof are furnished, by a corporation, committee, association or other unincorporated group, the announcement required by this section shall disclose the name of such corporation, committee, association or other unincorporated group. In each such case the station shall require that a list of the chief executive officers or members of the executive committee or of the board of directors of the corporation, committee, association or other unincorporated group shall be made available for public inspection at one of the radio stations carrying the program.

(e) In the case of programs advertising commercial products or services, an announcement stating the sponsor's corporate or trade name or the name of the sponsor's product, shall be deemed sufficient for the purposes of this section and only one such announcement need be made at any time during the course of the program.

Broadcasts by candidates for public office. (a) Definitions. A "legally qualified candidate" means any person who has publicly announced that he is a candidate for nomination by a convention of a political party or for nomination or election in a primary, special, or general election, municipal, county, state or national, and who meets the qualifications prescribed by the applicable laws to hold the office for which he is a candidate, so that he may be voted for by the electorate directly or by means of delegates or electors, and who

(1) Has qualified for a place on the ballot; or

(2) Is eligible under the applicable law to be voted for by sticker, by writing in his name on the ballot, or other method, and (i) has been duly nominated by a political party which is commonly known and regarded as such, or (ii) makes a substantial showing that he is a bona-fide candidate for nomination or office, as the case may be.

(b) General requirements. No station licensee is required to permit the use of its facilities by any legally qualified candidate for public office, but if any licensee shall permit any such candidate to use its facilities, it shall afford equal opportunities to all other such candidates for that office to use such facilities: Provided, That such licensee shall have no power of censorship over the material broadcast by any such candidate.

(c) Rates and practices. The rates, if any, charged all such candidates for the same office shall be uniform and shall not be rebated by any means, directly or indirectly; no licensee shall make any discrimination in charges, practices, regulations, facilities, or services for or in connection with the service rendered persuant to these rules, or make or give any preference to any candidate for public office or subject any such candidate to any prejudice or disadvantage; nor shall any licensee make any contract or other agreement which shall have the effect of permitting any legally qualified candidate for any public office to broadcast to the exclusion of other legally qualified candidates for the same public office.

(d) Inspection of records. Every licensee shall keep and permit public inspection of a complete record of all requests for broadcast time made by or on behalf of candidates for public office, together with an appropriate notation showing the disposition made by the licensee of such requests, and the charges made, if any, if request is granted.

Rebroadcast. (a) The term "rebroadcast" means reception by radio of the program1/ of a radio station, and the simultaneous or subsequent retransmission of such program by a broadcast station.2/

(b) The licensee of an F-M broadcast station may, without further authority of the Commission, rebroadcast the program of a United States standard, F-M or noncommercial educational broadcast station, provided the Commission is notified of the call letters of each station rebroadcast and the licensee certifies that express authority has been received from the licensee of the station originating the program.3/

(c) (1) The licensee of an F-M broadcast station located within a State or the District of Columbia may, without further authority of the Commission, rebroadcast on a noncommercial basis a noncommercial program of a United States international broadcast station.

(2) The licensee of an F-M broadcast station located in any territory or insular possession of the United States may, without further authority of the Commission, rebroadcast any program of a United States international broadcast station.

(3) In the case of any rebroadcast under the provisions of this paragraph (c) the Commission shall be notified of the call letters of each station whose program is rebroadcast and the licensee shall certify that express authority has been received from the licensee of the station originating the program.

(b) No licensee of an F-M broadcast station shall rebroadcast the program of any United States radio station not designated in (b) or (c) above without written authority having first been obtained from the Commission upon application (informal) accompanied by written consent or certification of consent of the licensee of the station originating the program.4/

By Order No. 82, dated and effective June 24, 1941, until further order of the Commission section (d) of Rebroadcasting is suspended only insofar as it requires prior written authority of the Commission for the rebroadcasting of programs originated for that express purpose by United States Government radio stations.

1/ As used in this section, program includes any complete program or part thereof.

2/ In case a program is transmitted from its point of origin to a broadcast station entirely by telephone facilities in which a section of such transmission is by radio, the broadcasting of this program is not considered a rebroadcast.

3/ The notice and certification of consent shall be given within 3 days of any single rebroadcast, but in case of the regular practice of rebroadcasting certain programs of a standard or F-M broadcast station several times during a license period, notice and certification of consent shall be given for the ensuing license period with the application for renewal of license, or at the beginning of such rebroadcast practice if begun during a license period.

4/ The broadcasting of a program relayed by a relay broadcast station or studio transmitter link is not considered a rebroadcast.