TELEVISION EQUIPMENT THEORY AND OPERATION

MANUAL FOR

TELEVISION TECHNICAL TRAINING PROGRAM

RCA

BROADCAST EQUIPMENT SALES
ENGINEERING PRODUCTS DEPARTMENT
RADIO CORPORATION OF AMERICA
CAMDEN, N. J.

TELEVISION EQUIPMENT

THEORY AND OPERATION

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MANUAL

FOR

TELEVISION TECHNICAL TRAINING PROGRAM

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ENGINEERING PRODUCTS DEPARTMENT
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CAMDEN, NEW JERSEY

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OBJECTIVE

The purpose of this program is to provide customer personnel with technical instruction in operation and maintenance of RCA Television Transmitting and Studio Equipment.

BROADCAST EQUIPMENT SALES
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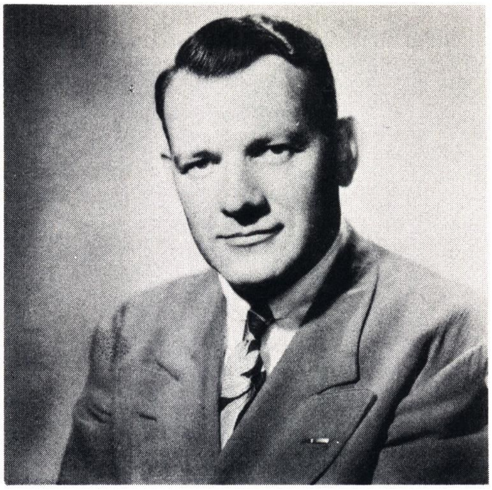

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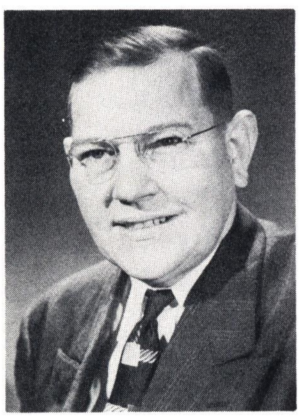

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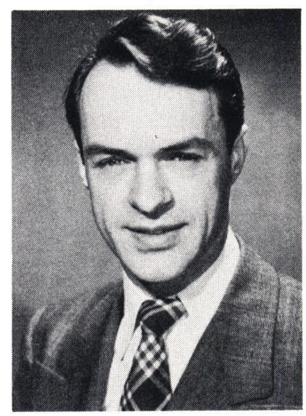

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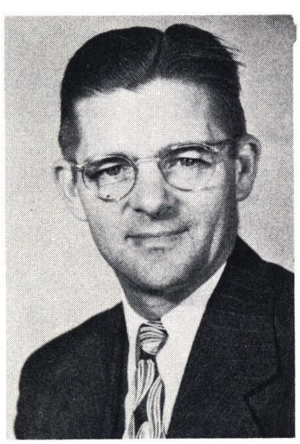

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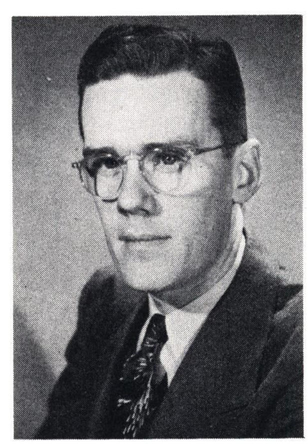

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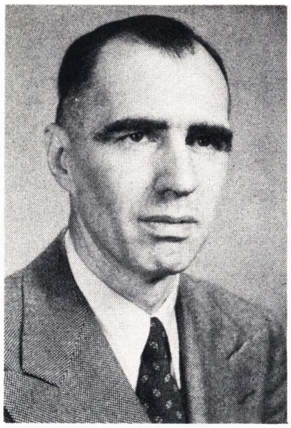

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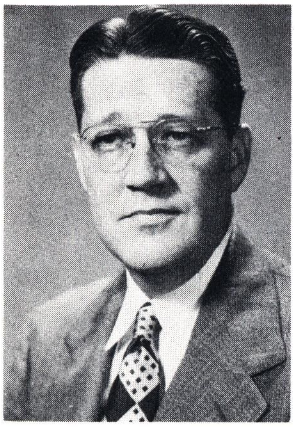

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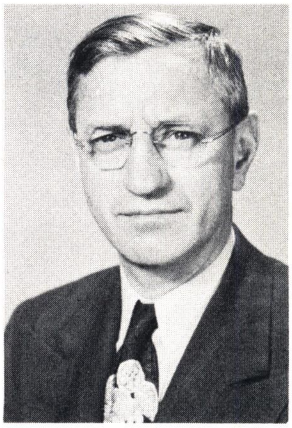

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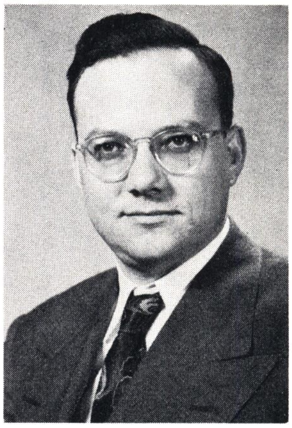

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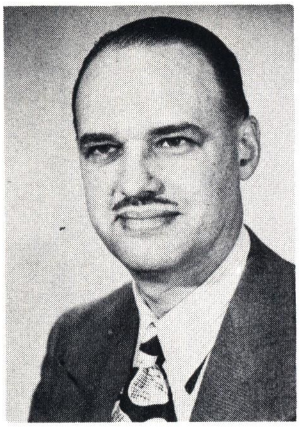

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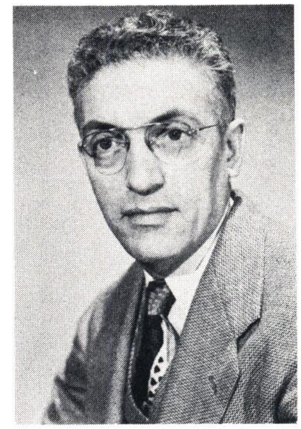

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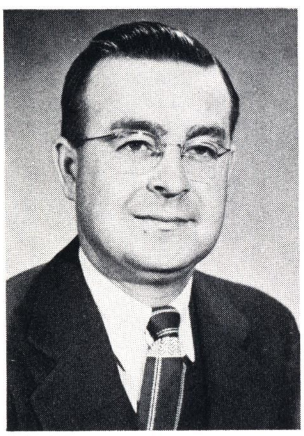

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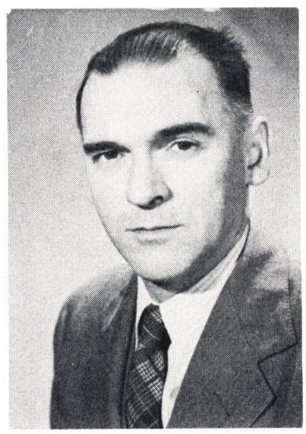

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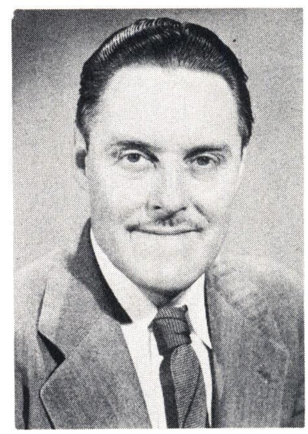

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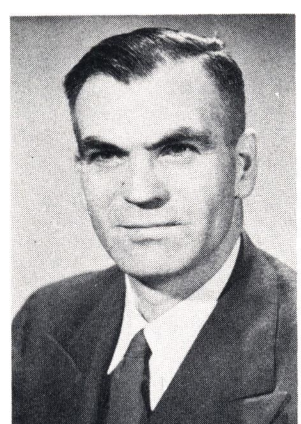

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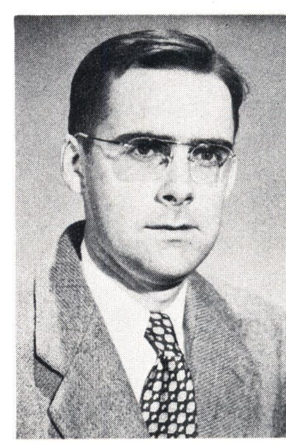

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TELEVISION TECHNICAL TRAINING PROGRAM

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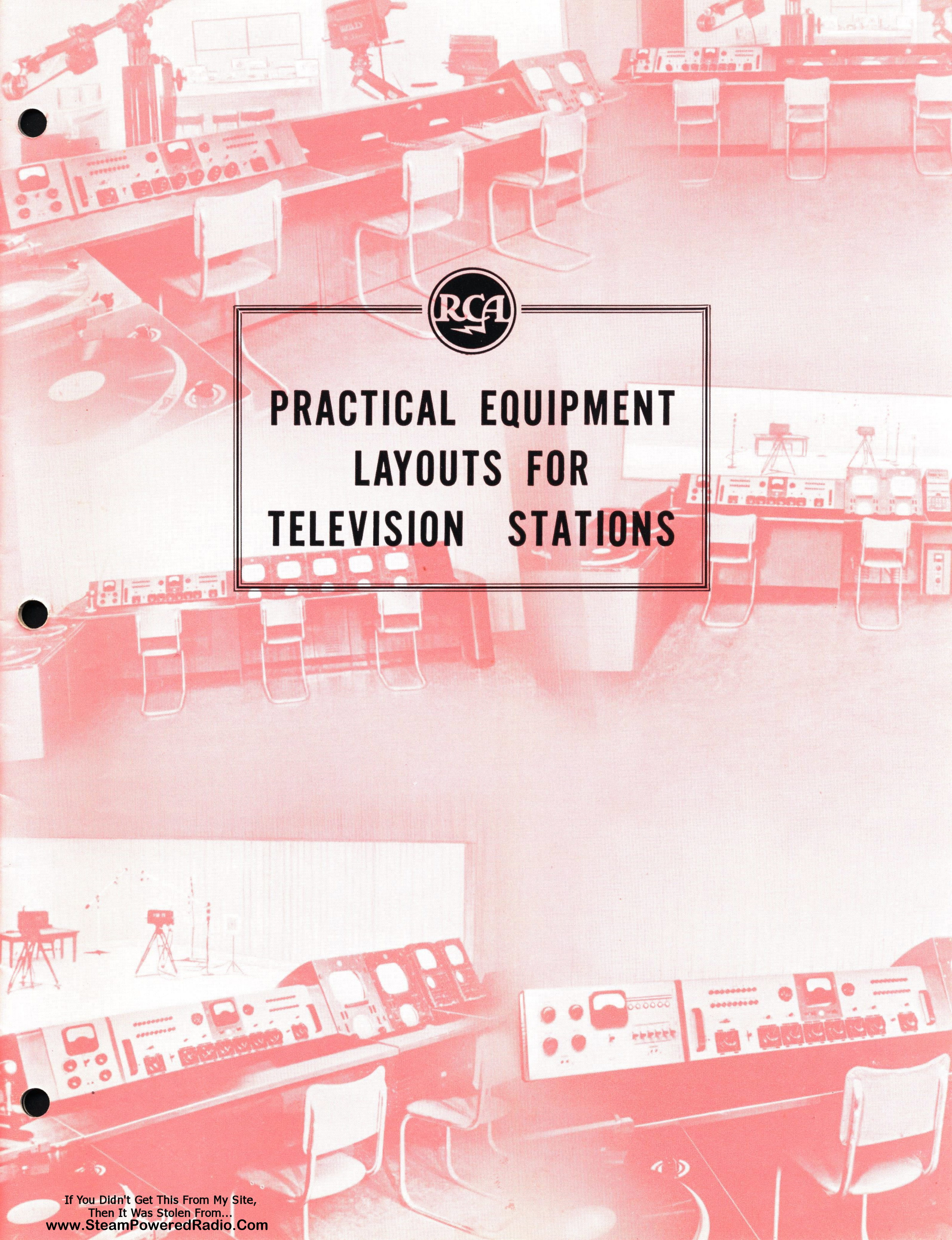
SECTION I

TELEVISION STATION LAYOUTS



RCA

PRACTICAL EQUIPMENT LAYOUTS FOR TELEVISION STATIONS

Reprinted from

BROADCAST NEWS

Number 52, December 1948

PRACTICAL EQUIPMENT LAYOUTS FOR TELEVISION STATIONS

Introduction

The equipment required for a television studio installation varies widely depending on the type of station, the size of the community in which it is located, and the magnitude of the station operation. In this respect it differs greatly from the equipment requirement of the transmitter part of a TV installation which, with the exception of transmitter power, is much the same for all stations.

If the station is a network origination point, located in a large city, it will probably be a multiple-studio installation requiring a large number of cameras, associated control equipment, master control equipment and elaborate distribution facilities. If it is a non-network station in a large city it will probably require almost as much camera and control equipment (due to the fact that it must compete programwise with the network stations), but it will not, of course, require the distribution facilities. On the other hand a network station in a medium-sized community, because it will receive most of its programs from the network, will need only relatively simple studio facilities. In some instances, network stations in small communities may not have any origination facilities except a slide projector for station identification, and a simple film pickup system.

This wide range of requirements, plus the fact that many stations will wish to install minimum equipment and "grow" with the development of the audience, led RCA engineers to the conclusion that TV studio equipment should be made of carefully planned units so coordinated that they could be easily fitted together to provide almost any desired combination of facilities. This is essentially the "building block" idea which is today employed in many types of industrial apparatus. However, in the design of RCA TV units the idea has been carried further in that the equipment has been broken down into smaller units. Thus, when expanding a system made up of RCA TV units it is usually not necessary to add a whole desk or console. For instance, another camera (either studio or film) can be added to an existing system by the addition of a 14 inch wide section to the video console. Single amplifiers, monitors, relay units or the like can be added at will. Moreover, all of these units are designed to operate at a standard level and into a standard impedance. Thus input and output connections can be brought out to jacks, so that units can be patched in or out as desired (thereby providing for temporary modifications of the system as may be required).

The six system layouts described in this article have been chosen to illustrate the wide range of equipment combinations which are practical. For the most part these are layouts actually in use at existing studios or now being installed at stations under construction. Thus they represent a large amount of thoughtful planning and are based, to the largest possible degree, on actual operating experience. There are, of course, many modifications of these systems, and numerous in-between-designs, which will occur to station engineers. Using RCA TV units it will be relatively easy to make such modifications as may be necessary to meet the specific requirements of individual stations.

Of the six different layouts to be described, types A, B, and C utilize only one live-talent studio and a single control room. The single control room is a combined studio control room, film control room and master control room. The Type D station also has only one live-talent studio; but it has two control rooms, one for the live-talent studio and one for the master control room. The Type E station is a deluxe arrangement of the Type D; including a program console, which provides additional facilities over Type D. Finally, the Type F Station is a master layout employing two studios, each with its own control room, and separate film control and master control rooms.

General Considerations

All TV studio installations—large or small—are alike in many respects. The difference in size, for instance, is mostly a matter of the number of studios involved. The single studio of a small station with its associated control room is almost identical to one of the studios and associated control room of the large station. Thus the general arrangement of the equipment in the control room proper is very much the same in all stations. Moreover, the equipment for all stations is made up from the same basic units. And, finally, the basic control system used in all of them is the same.

Because of these similarities it is worthwhile to discuss some of the basic considerations in a general way before beginning the detailed description of the six equipment layouts. Inasmuch as this part of the discussion has to do with rather elementary aspects of the subject those with some previous background or experience may wish to skip this part and continue with the detailed descriptions of the six layouts which begin on Page 18.

Basic TV Studio Arrangement

It is not the purpose of this article to discuss the design of TV studio buildings.[2] However, several partial floor plans have been included in order to indicate relative sizes and the general arrangement of studios, control rooms, workshops and dressing rooms.

The dimensions of these studios, as well as the control rooms, may seem large, by broadcast standards. Experience indicates, however, that the dimensions shown are close to the practical minimum. TV studios should be large enough to provide for as many as two or three sets, which may be successive scenes in a program; while control rooms should be made large enough to admit additional equipment as the station grows. As a matter of fact, the floor plan suggested for the Types A and B small stations will serve also for the larger Type C station. Because large studios are used, the control room window can be quite large compared to that of most broadcast stations. This is an advantage in that the control room audio and video consoles when placed end to end require much more space than audio alone. Of course it is not absolutely necessary for all the technical operators to be able to see into the studio. It is important, however, that the program director be able to see all of the studio action from his position in the con-

[2] For a discussion of TV building design see "Facilities for TV Housing", Broadcast News No. 50, Page 8.

trol room. In order to give all of the personnel in the control room a better view of the studio, the control room floor is usually elevated about two feet above the studio floor level.

There are several ways of arranging the equipment in the control room. RCA engineers are inclined to recommend that all the equipment consoles; i.e., audio, video and director's (if used) be placed side by side directly in front of the control room window. A somewhat different method, preferred by some broadcasters, is to place the program director and audio operator on a platform, (Fig. 11) elevated two or three feet above the control room floor. This particular arrangement is illustrated and described more fully in the layout for the Type C station.

At least one announce booth is essential in a TV station layout. Such a booth is provided with the necessary audio facilities and a picture monitor. It enables a commentator, for example, to see the picture upon which he is commenting, so that he can follow the action accurately.

This booth may be located in one corner of the film control room, or it may be located just outside the master control room. If one announce booth is to serve also for station identification, it may be advisable to locate it outside the master control room, and construct it so that visual "cue" can be given from the master control room.

Basic TV Studio Equipment

Most of the units which make up the video system of a television station are counterparts of the audio units in a broadcast station. The camera itself corresponds to the microphone, the camera amplifier to the microphone preamplifier and so on.[1] In general, these television units are arranged in much the same manner as the corresponding audio units of a standard broadcast station. The output of each studio or film camera is fed into one of the input positions on a video control console in the control room. At this console position, the video signals from the cameras are mixed (or switched) in the same manner as microphone and transcription inputs are mixed at the audio console. From the video console the picture signal is fed either directly to the transmitter line or to a master control room where it is mixed with signals from the studio, the network line, or outside points. Here again the operation is directly comparable to that of a standard broadcast setup.

There are several major differences, however, in the video setup. One of these is due to the fact that the video output of the camera has several qualities, such as brightness, contrast and focus, which require constant supervision. This operation is roughly comparable to that of riding gain in an audio setup. It is, however, a much more complicated process, and for this reason is generally separated from the mixing or switching function. In all but the smallest setups, this supervision of the individual camera signals is exercised by a "video operator" who sits at a video console (Fig. 7). This console is made up of sections usually referred to as camera control units. There is one of these control units for each studio camera and one for each film camera. Each unit (Fig. 5) contains a picture monitor showing at all times the picture picked up by the camera

[1] All of the RCA television equipment units referred to in this article are described in detail in individual equipment bulletins available from the Television Equipment Sales Section, RCA Engineering Products Dept., Camden, N. J.

RCA UNIT-BUILT EQUIPMENT LENDS ITSELF

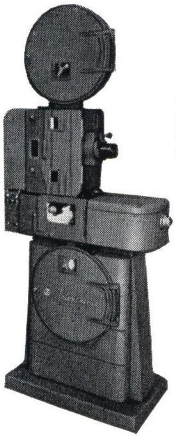


FIG. 1. Type TP-35A 35mm Television Film Projector which enables television broadcasters to use standard 35mm motion picture film as program material.

FIG. 3. Type TC-5A Program Director's Console. This console provides the program director in the control room with pictures of the scenes being picked up by the studio cameras, so that he can choose the picture to be transmitted.

FIG. 2. Type TK-20A Film Camera. This camera converts motion pictures projected from 16mm or 35mm projectors to video signals for television transmission.

FIG. 4. Microphone Boom and Perambulator. This boom enables the audio man in the studio to pickup the sound while keeping the microphone out of the view of the camera.

it is associated with. It also contains an oscilloscope for "waveform" monitoring and all of the necessary controls for adjusting the brightness, contrast, focus and other attributes of the particular camera picture. The video operator uses these controls to keep the several camera pictures in optimum adjustment at all times. Thus, the technical director, or whoever does the switching, is free to concentrate on the action without worrying about the camera adjustments.

Another major difference in the video setup is occasioned by the fact that video signals cannot be "piped" about quite as freely as audio signals. For this reason it is usually necessary (in all but the smallest systems) to employ relay switching. Thus, the video switching setup of most stations will correspond more nearly to the relay type of audio switching used in the larger broadcast station and network studios.

The audio equipment used in a television station is very much like that used in a standard broadcast station. There are, however, several minor differences. One is occasioned by the fact that the microphones must be kept out of sight. This usually requires either more microphones or else the use of elaborate boom mounts (Fig. 4). Another is the desirability of being able to add background sound (from a transcription turntable) and have it heard in the studio (which involves some changes in control circuits since most standard audio equipments are interlocked to prevent this).

The audio control requirements for TV also differ somewhat from those used in AM and FM broadcasting. In TV studios, microphones are usually suspended on the ends of movable boom stands. The boom operator, under the direction of the audio engineer, maintains the placement of the boom microphones for best sound pickup. He must also keep the boom and microphone out of the view of the camera. Good communication, therefore, must be maintained between audio engineer and boom operator. This necessity of directing the microphone movement (in addition to his normal job of riding gain) keeps the audio operator much busier than in standard broadcasting.

Because the video and audio operators are so busy exercising their individual monitoring functions, it is standard TV practice to place the actual switching (or mixing) operation in the hands of a third technician who is usually the technical director. The location and arrangement of facilities for switching varies widely with the type of setup (and with the personal preference of station planners). In medium-sized stations, a simple but effective arrangement consists in adding to the video console two additional monitor sections. These sections (Fig. 5) are similar in size and appearance to the camera control units. One of these acts as a master (or program) monitor. On its screen appears at all times the picture output of the control room (i.e., the picture being sent to the transmitter or the master control room). There is a space on this unit for a panel containing a push-button switching system with lap-dissolve levers, signal lights, etc. The technical director uses these controls to select the picture for transmission. The monitor in the unit gives him a constant visual check on the transmission. Ordinarily a second unit, similar in size and arrangement, is located next to the master monitor. This second monitor is used as a "preview" monitor. The technical director uses a set of push-buttons on it to select the camera input he

TO A VARIETY OF TV STATION LAYOUTS

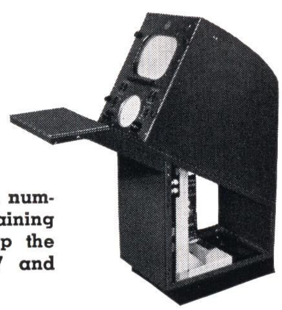


FIG. 5. Video Console Section. A number of these sections, each containing 10-inch picture monitors, make up the video consoles shown in Fig. 7 and in the layout photos.

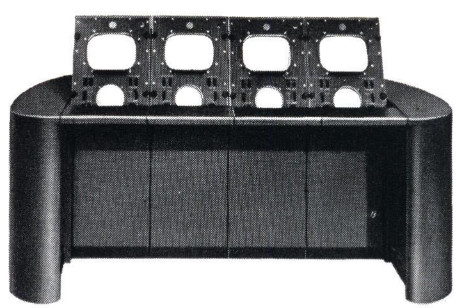


FIG. 7. Video Console. These sections can be individually equipped as TK-10A camera controls, TS-10A camera switching systems, and "preview" and program monitors sections.

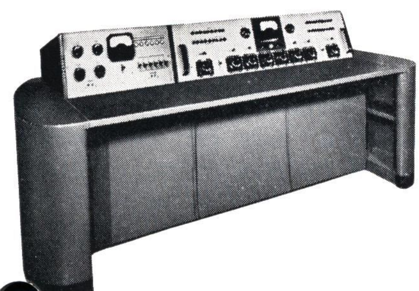


FIG. 6. Television Audio Console. This console is the control center for the audio part of the television program.

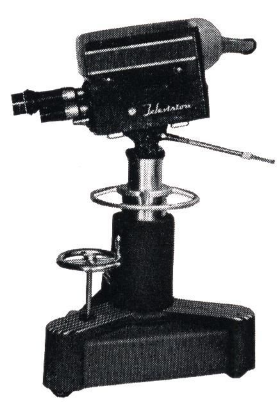


FIG. 8. TK-10A Studio-type Camera and Pedestal.

proposes to use next. This allows him to monitor (for quality and action) his upcoming shot. This monitor may also be used to take visual "cue" from a preceding program by switching to the video line from the preceding origination point.

The "master" and "preview" monitors obviously do not have to be a part of the video console. They may, if desired, be located some distance away as, for instance, on an elevated platform beside the program director's position. Several such alternatives are shown in the equipment layouts which are described in the following pages. Also described are several different types of switching controls. However, the general operation is the same in all cases.

It will be evident by now that the major difference between TV and AM (or FM) equipment layouts is in the relative complexity of the former. In addition to the three technicians mentioned above, the active personnel in a TV studio control booth usually includes a program director and one or more assistants. All of these people must be provided with some monitoring facilities. Here again there are wide differences between setups. In the smallest layouts, the program people simply peek over the shoulders of the technicians. In the most elaborate setups, the program director has his own program console (Fig. 3). Various program monitoring setups are described in connection with the layout description on following pages.

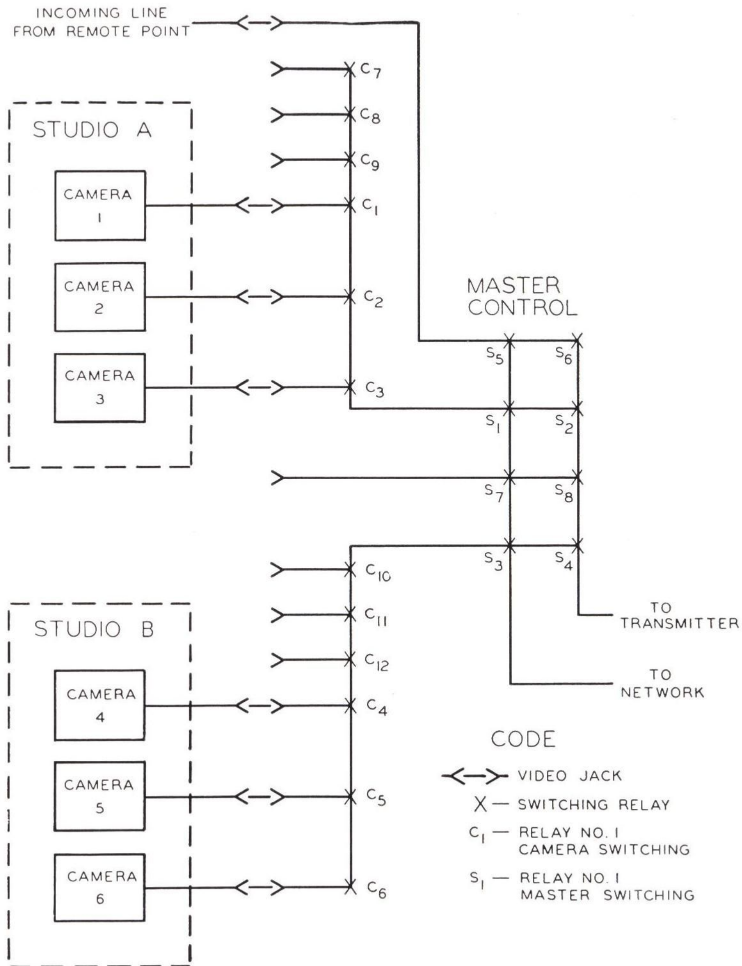


FIG. 9. Simplified diagram of the camera switching and master switching systems. Jack panels, rack-mounted near the switching relays, permit program material to be patched directly into any control position.

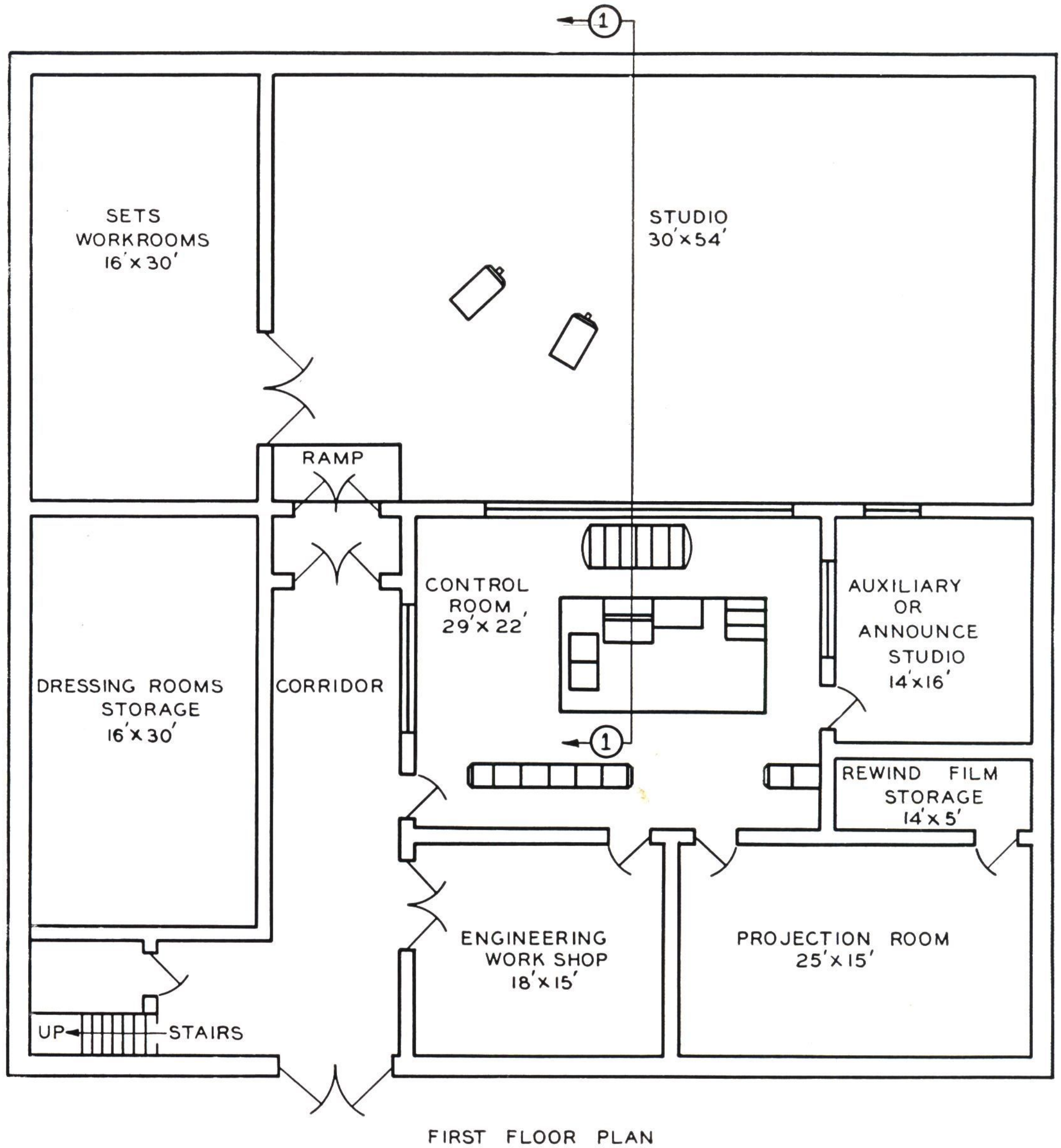
Basic TV Studio Control System

The control systems included in the television layouts treated in this article are similar in arrangement to those used in broadcast stations of corresponding size. Thus, in this respect also many of the operational procedures used in AM broadcasting are carried over into television broadcasting.

The average television program consists of a succession of studio pickups, plus the occasional inclusion of signals from remote points or other studios. A simple example of the latter is the insertion, into the program, of a station identification slide or short picture sequence originating in the film projection room. Another is the occasional (although less frequent) insertion of outdoor scenes picked up by field equipment and fed to the station by line or microwave relay. Thus, even though the major part of any one program will originate in one studio, with control of the program centered in its control room, some provision must be made for coordinated control of the remote signals, as well as the signals emanating from the projection room and other studios. In almost any television setup, switching from local to remote signals can be done, of course, in master control. But a feature of the layouts described here (with the exception of Types A, B and C which have a single combined control room) is that the remote signals and the signals from other studios may also be brought into any of the camera switching systems, thereby allowing control of all program source material within any studio control room, as well as in master control. Fig. 9 is a simplified drawing of such an arrangement. Note that video plugs and jacks are employed between the cameras and camera switching relays, and at one point, into the master switching relays. By locating all these jacks and plugs in one room such as master control, remote signals as well as signals from the projection room can be patched into the control rooms of either studio. With this arrangement, the program director in the studio control room can introduce outside signals at any time into the studio program line. Another useful feature of this system is that the output from a studio camera or film camera can be patched directly into the master switching relays (S7 and S8). This permits a test pattern or announcement slide to be placed on the transmitter line without disturbing the operation of either studio, which may be engaged in rehearsal or feeding a network program.

It will be noted that the system just described closely parallels that used in broadcasting, except that the cameras take the place of microphones and relays are used instead of key switches. The audio equipment used with the video equipment is arranged in the same manner and can be arranged to have the corresponding audio master switching relays (equivalent to the video master switching relays S1, S2, S3 and S4) interlocked so that both sets of relays are operated from one set of controls. For simplification, the description of video and audio facilities in the layouts has been handled separately. The audio facilities are outlined at the end of the article.

FIG. 10. This partial floor plan shows the space and housing facilities required by the standard size station for the origination of studio and film shows. Clients' viewing room is located above the studio control room.



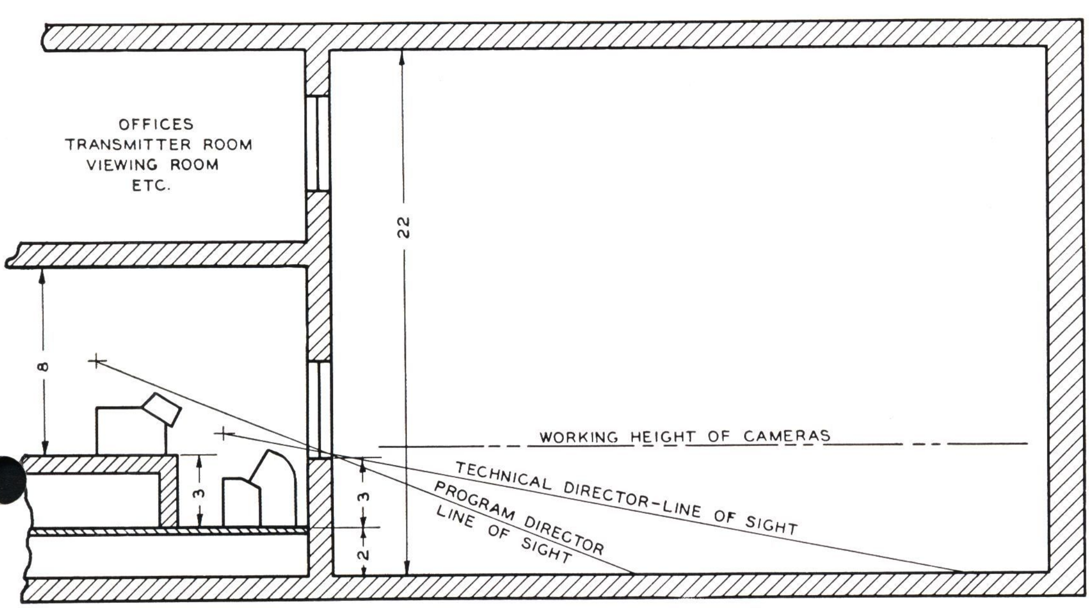


FIG. 11. (Left) Cross-section of control room of Fig. 9, shows elevation of program director to provide him with a good view into the studio.

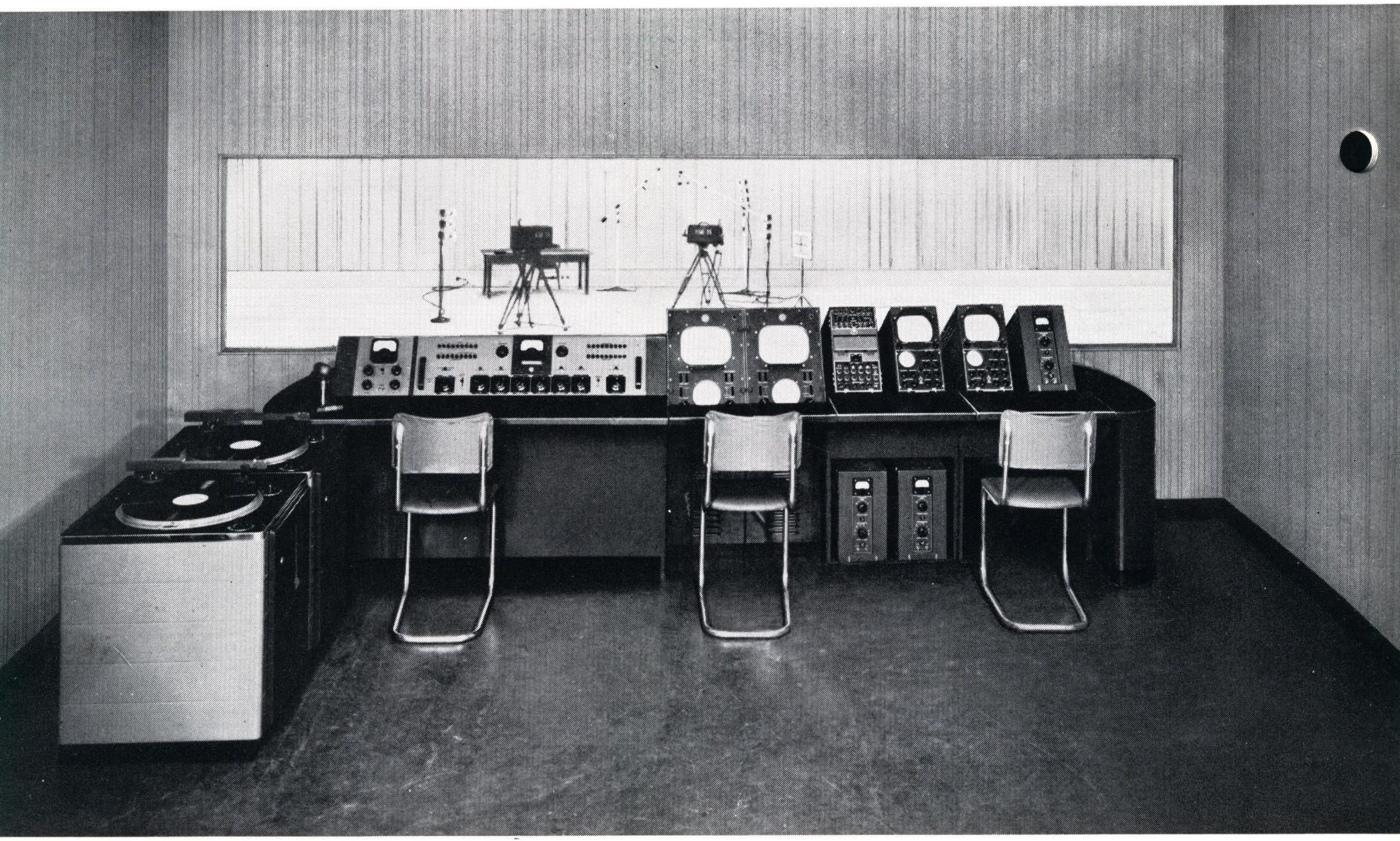


FIG. 12. Typical Control Room for the Type A Small Television Station. Two console sections with picture monitors (center) are standard studio control room units. Portable field-type units on the right, when not used for outdoor pickups, are placed in the control room for production of local studio shows. At left are transcription turntables and the audio control console.

TYPE A LAYOUT FOR A STATION WITH ONE LIVE TALENT STUDIO, FILM PROJECTOR AND CONTROL ROOM

This plan for a small television station provides the facilities necessary for broadcasting the four main types of television programs; namely, (1) network programs received by coaxial cable from the studios of a network key station, (2) standard 16mm entertainment and commercial films, (3) local studio programs, including live talent, and (4) programs "picked up" at points remote from the studio with portable field equipment, and which are sent to the station via coaxial line.

Broadcasting of these four types of programs with an equipment which represents a relatively low initial investment is made possible by dual use of the RCA Television Field Equipment. This equipment, which consists of portable field cameras, plus small-size, easily portable auxiliary units, is especially designed for use in picking up programs from locations outside the studio—such as boxing matches, football games, nightclubs and the like. In medium-size and larger television stations it will, most likely, be used exclusively for that purpose. However, in small stations (where studio programs may be relatively few in number) it can also be used, at least in the initial stages, as the regular studio equipment. Special, inclined-top tables can be used in the control room to accommodate the camera control units. These tables when placed side by side with the audio or video consoles form an attractive studio control room layout. The field type cameras when used in the studio can be mounted on tripods fitted with mobile dollies. Or, of course, the cameras can be mounted on studio pedestals, or even on crane-type dollies, if desired. Technically, the field type cameras operate very well in the studio.

The facilities for the Type A layout include: one live-talent studio, a film projection room, a combined studio and film control room and an announce booth. In larger stations, the projection room has a control room too, but in this plan for the small station the studio control room houses the film camera control equipment as well as the studio camera control equipment. Thus, it becomes a combined film and studio control room. Master switching, i.e. between studio, film and remote signals, is also done in the studio control room in this layout.

Studio Equipment

Equipment for the studio of the small station consists of two RCA field cameras plus the necessary lighting and props required to put on live-talent shows. The field cameras are complete with electronic viewfinders and folding tripod mountings. As previously mentioned, special studio pedestals or crane dollies can be made a part of the studio equipment to enable the cameramen to dolly the cameras, as well as move quickly between two or three "sets" methodically arranged in the one studio. Power for the cameras is supplied through the camera cable from the studio control room. The cameras, microphones, and their mountings, therefore, are the only items of television equipment required in the studio.

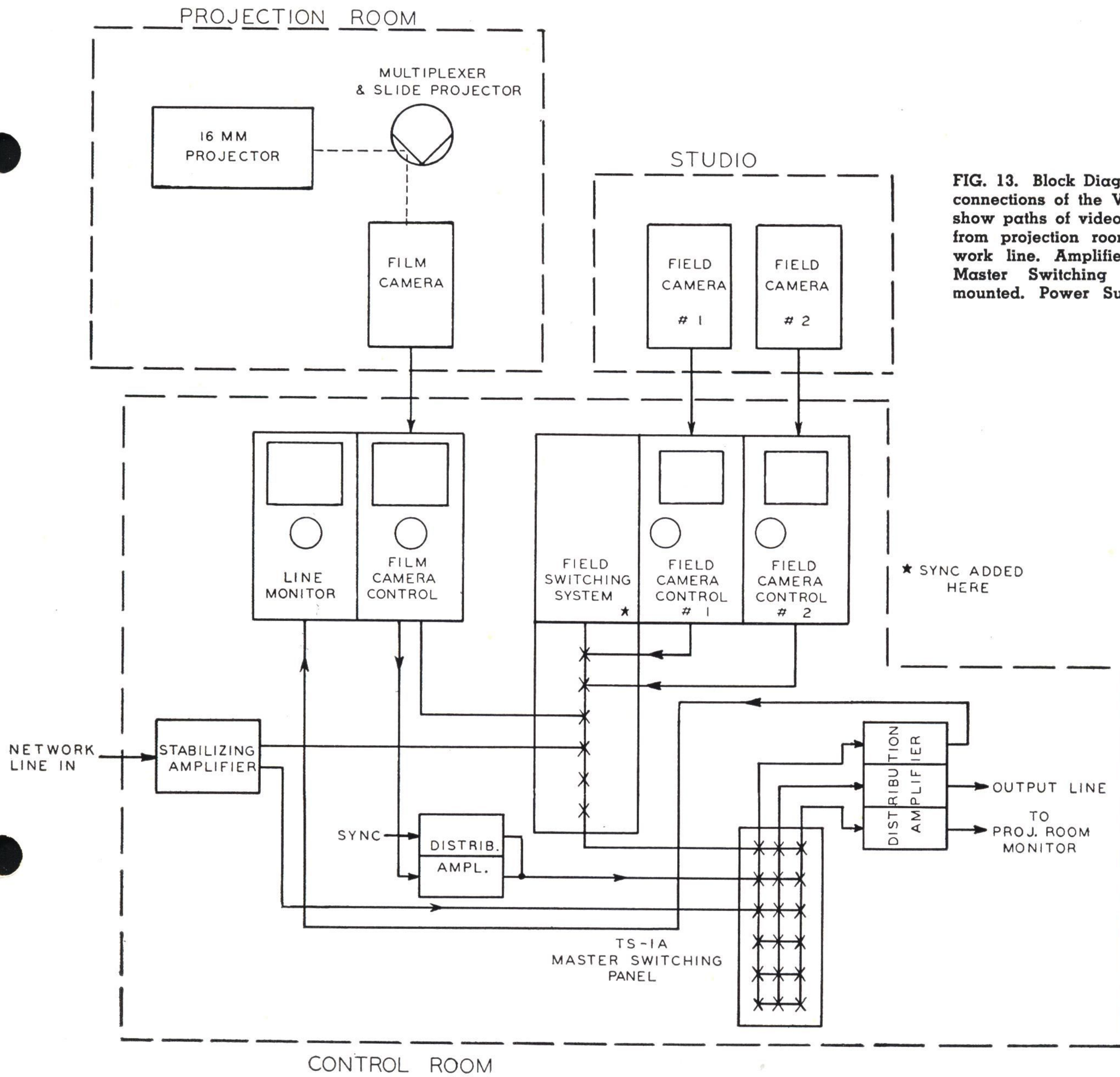


FIG. 13. Block Diagram Showing Interconnections of the Video Units. Arrows show paths of video signals emanating from projection room, studio and network line. Amplifiers and the TS-1A Master Switching Panel are rack-mounted. Power Supplies not shown.

Control Room Equipment

When the two field cameras are used in the studio for producing live-talent shows, the complete control room equipment will be that shown in Fig. 12. The major items consist of a three-operator console (requiring a program director, one audio and one video operator), two audio turntables, and equipment racks to house the amplifiers, sync generator, and power supplies. The control room console is actually made up of separate audio and video units. But these units are designed to go together to provide a console with unified appearance. The audio control equipment shown in the photos consists of two consolettes. The RCA 76 consolette is the large one next to the video monitors, and the small consolette to the left provides an additional audio channel and private telephone circuits. This audio equipment is described more fully following the description of these layouts.

At the video operator's position are (a) the two field type camera control units for the cameras in the studio, (b) a field type switching system, and (c) three field type power supplies. Each of the two camera control units contains a 7-inch picture tube, waveform oscilloscope and manual controls for making the necessary adjustments of the picture signals. It is through manipulation of these camera controls that the video operator, while watching the picture produced by each camera, controls its technical aspects. He makes sure each picture has the proper shading and contrast, and that the video and sync levels are correct, as indicated by the built-in oscilloscopes. Moreover, he may, at the request of the program director seated beside him, switch the selected signal into the program line; although, it is possible that the director may choose to do his own switching, while at the same time previewing these signals on the picture tubes of the camera controls. The field switcher, which serves for switching any of the incoming signals (including network, film or remote line) to the transmitter room, is located close to the program director for that purpose.

In this plan A setup for the small station, the program director is seated before two standard control room units (a) a line monitor and (b) a film camera control unit. Both of these units are installed in standard studio console housings. In the upper compartment of each housing is a TM-5A Master Monitor, which has a 10-inch picture tube and a 5-inch CRO tube. This is the monitor which is used in all RCA standard studio and master control room equipments. It is illustrated in Fig. 5, Page 15.

The film camera control has a function similar to that of the field camera control unit in that it supplies the blanking and driving signals for the film camera, and also reproduces a preview picture of the signal generated by the film camera. Controls for adjustment of picture levels and shading are located on the console. The film camera control is located adjacent to the video operator so that he can conveniently observe the picture being displayed on the monitor and keep it at all times technically suitable for broadcasting.

The line monitor alongside the film camera control provides the director with a large bright picture of the video signal being sent (through a rack-mounted master switching panel) to the transmitter room. This picture appears on the monitor as the desired video signal is switched into the transmitter room line. There is a possibility that in some station layouts the control room rack which contains the master switching panel might be located so that the video operator could conveniently reach the switching panel. In this case, the switching panel would then become a master switching position which would enable the operator to view the selected signal on the preview monitor before he switched it to the transmitter room. In either case, of course, the camera control units provide excellent preview pictures, so that a special preview monitor is not an absolute necessity in this layout. Power supplies, for the line monitor and film camera control monitor are mounted in the control room equipment racks.

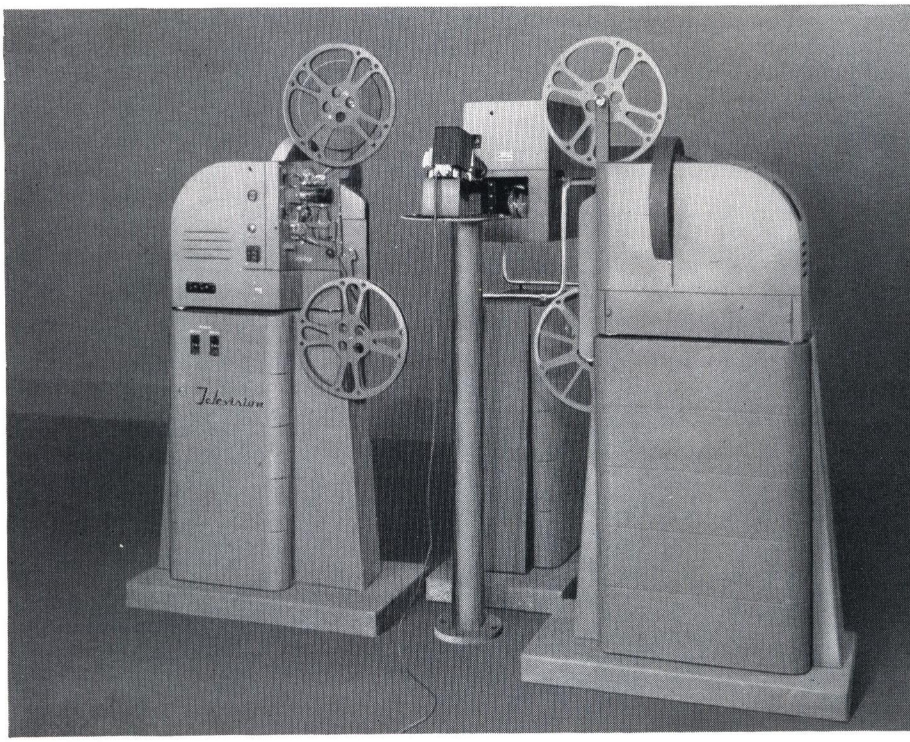
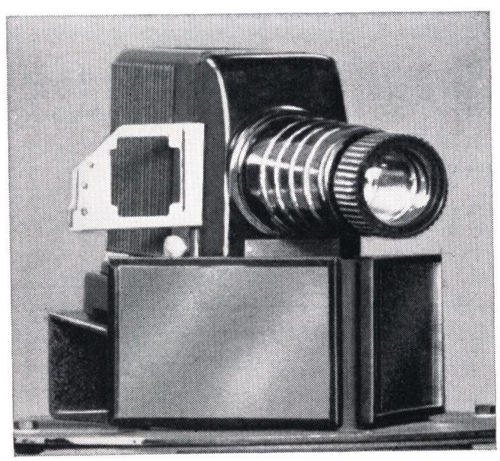
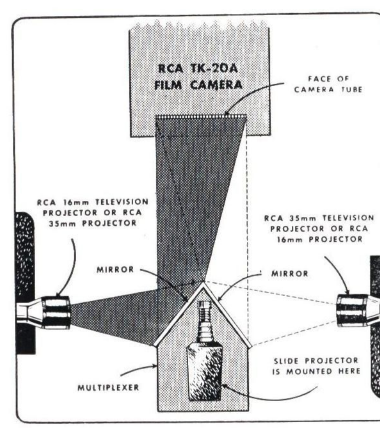


FIG. 14. (Above) Projection Room Setup Consisting of Two TP-16A 16mm Film Projectors, TP-9A Multiplexer (center) and TK-20A Film Camera (rear). Multiplexer operation is illustrated in diagram below. The TP-9A Multiplexer consists of two mirrors and provision for mounting a slide projector. Images from the slide projector, or from either film projector, focus directly into the film camera.





When the two field cameras are used outside the studio to make remote pickups, the two field camera control units, the three field type power supplies and the field switcher are removed from the control room and taken along with the field cameras and a field type sync generator. These units can be readily removed and replaced without disturbing other equipment in the control room.

During field use of the cameras, there will be three possible sources of program signals: (1) Remotes picked up by the field cameras and relayed by coaxial line to the control; (2) Film signals produced in the projection room; and (3) Signals coming in from an outside network. All these signals are fed to the rack-mounted switching panel in the control room, from which the program director can select the program signal and route it to the transmitter room. Any one of these signals can be viewed on the monitor, before it is switched to the transmitter line.

Projection Room Equipment

The film projection room equipment for this typical small station consists of a single 16mm film projector, a film camera for translating the projected picture into a video signal, a rack-mounted picture monitor, and a film multiplexer. The film multiplexer has two mirrors mounted at the required angle for projecting the images from either one of two projectors on the pickup tube in a single film camera. Use of the multiplexer is suggested in this layout because it is also fitted with a slide projector which can be used for station identification or for projecting other stills.

Technical Aspects

A functional block diagram of the equipment required by plan A of the small station is shown in Fig. 13. This diagram also shows the schematic arrangement of the various units.

Direction of signal flow between the units is indicated by the arrow-headed lines. Signals brought in through the net-

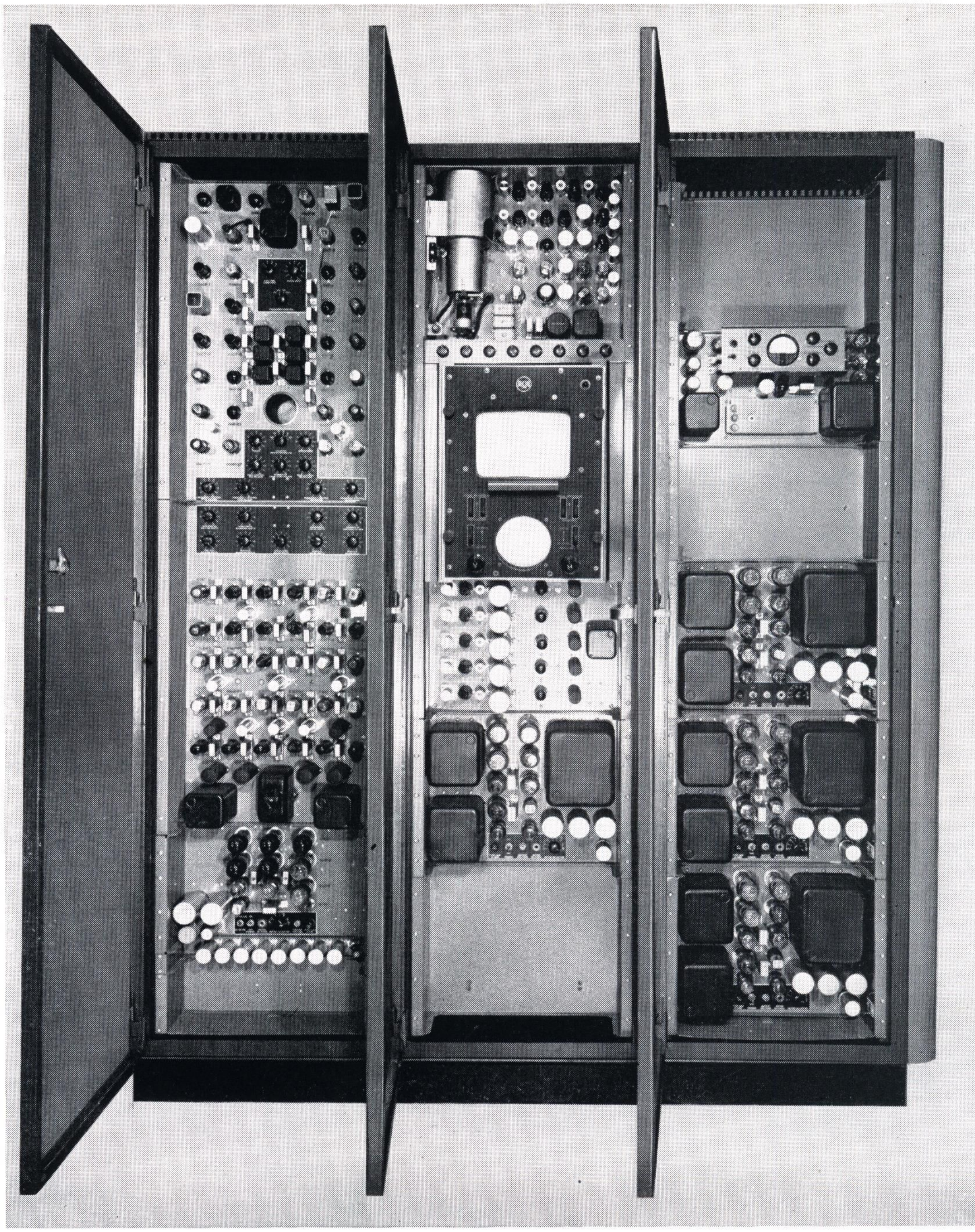


FIG. 15. The synchronizing generator, power supplies, amplifiers, and in some cases, video monitors are rack-mounted items. The three-section rack shown here contains the TG-1A Studio Sync Generator (left section), TK-1A Monoscope Camera, TM-5A Master Monitor, TA-1A Distribution Amplifier (center section), TRR relay receiver control, three WP-33A Power Supplies (right section).

work line or remote pickup line are already mixed with sync. This is the usual condition, the sync being added at the remote source of programming. On the other hand, the video signals from the film camera and from the field cameras (when they are used in the studio) obtain sync from the RCA Type TG-1A Studio Sync Generator (also located in the control room).

The switching system is designed so that the Type TS-1A Switching Panel, a rack-mounted unit, is a master switching point for selection of the major program sources for the transmitter. This makes it possible for the station to use the TS-30A Field Switching System solely for studio rehearsals, during which time the TS-1A can be used for switching between network or film signals. Two identical outputs from the film camera feed video to the field switcher and to the distribution amplifier. Sync is added in each of these units. Therefore, when the field switcher is used along with the field cameras to make remote pickups, and the TS-1A panel is in use at the control room, the distribution amplifier will combine sync with the film camera signal. Of course, the Type TG-10A Field Sync Generator can be used as an auxiliary for emergency operation. Like the other field units, this generator is a portable suitcase-type unit. It is used during outside pickups to supply driving signals to the field cameras and sync to their video outputs.

The Stabilizing Amplifier, through which the network programs pass, is a six-stage video amplifier with special keying and clipping stages. It removes low-frequency disturbances which may be present in the line, and enables the operator to match the sync and video levels of incoming signals to that of the signals generated by the local cameras.[3]

[3] For an explanation of the operation of the Stabilizing Amplifier see "How To Use The Stabilizing Amplifier" by John H. Roe, BROADCAST NEWS No. 49, Page 34.

TYPE B LAYOUT FOR A STATION SIMILAR TO TYPE A, MODIFIED TO PROVIDE ADDITIONAL PROGRAM FACILITIES

Plan B for the small television station differs from Plan A principally in the technical facilities available for programming. This plan requires slightly more control room equipment and therefore is not quite as economical from an initial investment standpoint. The additional equipment, however, requires no greater floor space than for Plan A, and the added facilities provided permit more flexible programming.

In Plan B, the program director can do more than simply switch from one signal to another. He can fade one camera out, fade the other in, mix the two camera signals in a lap-dissolve, or hold them superimposed. This unique feature, a means for very effective programming, is made possible by the use of RCA's TS-10A Studio Camera Switching System, which supplants the field switcher used in Plan A. This camera switching system (Fig. 17) is described in detail in one of the RCA television equipment brochures. It consists of a studio console section identical to the director's monitor section in Plan A. Like this section, it has a large-picture monitor mounted in the upper compartment, but in addition, a mixing amplifier chassis (which performs the technical process of dissolving signals) is mounted in the lower compartment.

In the Type B setup the program director can preview network and relay signals on the monitor directly in front of him before switching them into the transmitter room. There is a selector switch on the TS-10A panel which enables him to do this. Thus, the monitor in this setup can be both a "preview" and "line" monitor for the remote signals. Of course, the monitor in the film camera control section of the console serves for previewing the film signal, and the field camera controls provide preview of the studio cameras, so that this signal, if desired, is visible to the program director at all times.

The photo, Fig. 16, shows the equipment arranged in the control room. As can be seen, this layout is similar to that for Plan A. Actually it requires somewhat less space than Plan A because the field switching system is not needed in the control room, and the more elaborate TS-10A Switching System occupies space already available in the program director's preview section of the console.

As in Plan A, film facilities are furnished by a film camera, a 16mm projector and a slide projector located in the projection room. The film camera control is a console section similar to the studio camera controls, and is located with them in the control room. The projectionist utilizes a 10-inch picture monitor for cueing and for changeover. This monitor can

FIG. 16. (Below) Control Room for the Type B Small Station. This equipment layout utilizes the Type TS-10A Camera switching and lap-dissolving system, designed for studio control room use. Video units are identified in the block diagram, opposite page.

be mounted in the rack which houses the projector control mechanism, if desired. The Multiplexer is a device which has provisions for mounting a slide projector, and two mirrors mounted at the required angle for reflecting the images from either of two film projectors on the pickup tube in the film camera. Thus, by the addition of another projector, this setup can be easily made to handle multi-reel film shows.

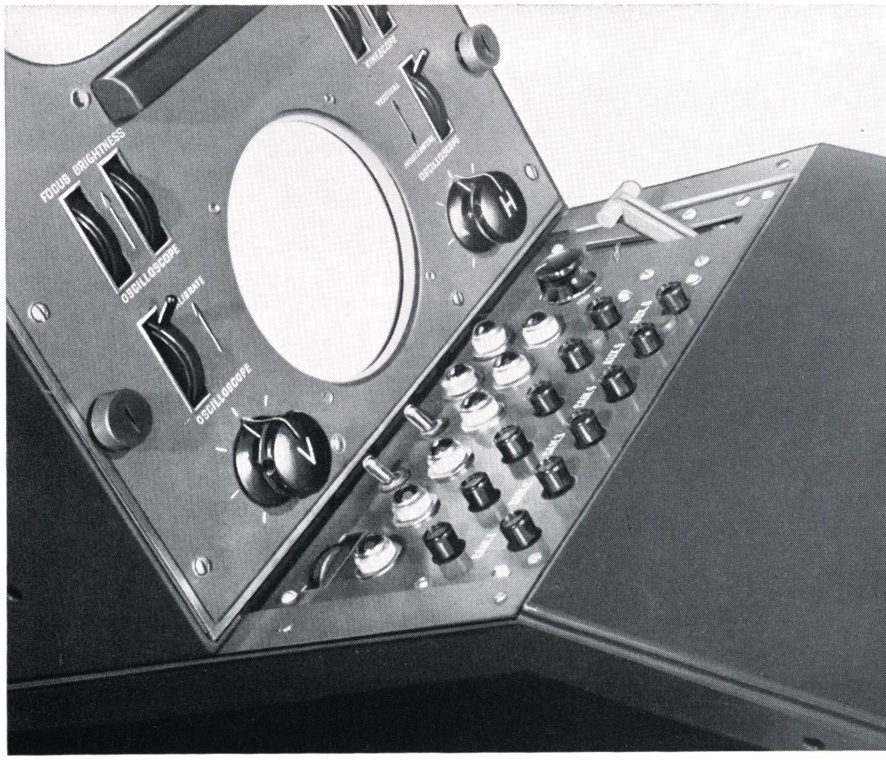
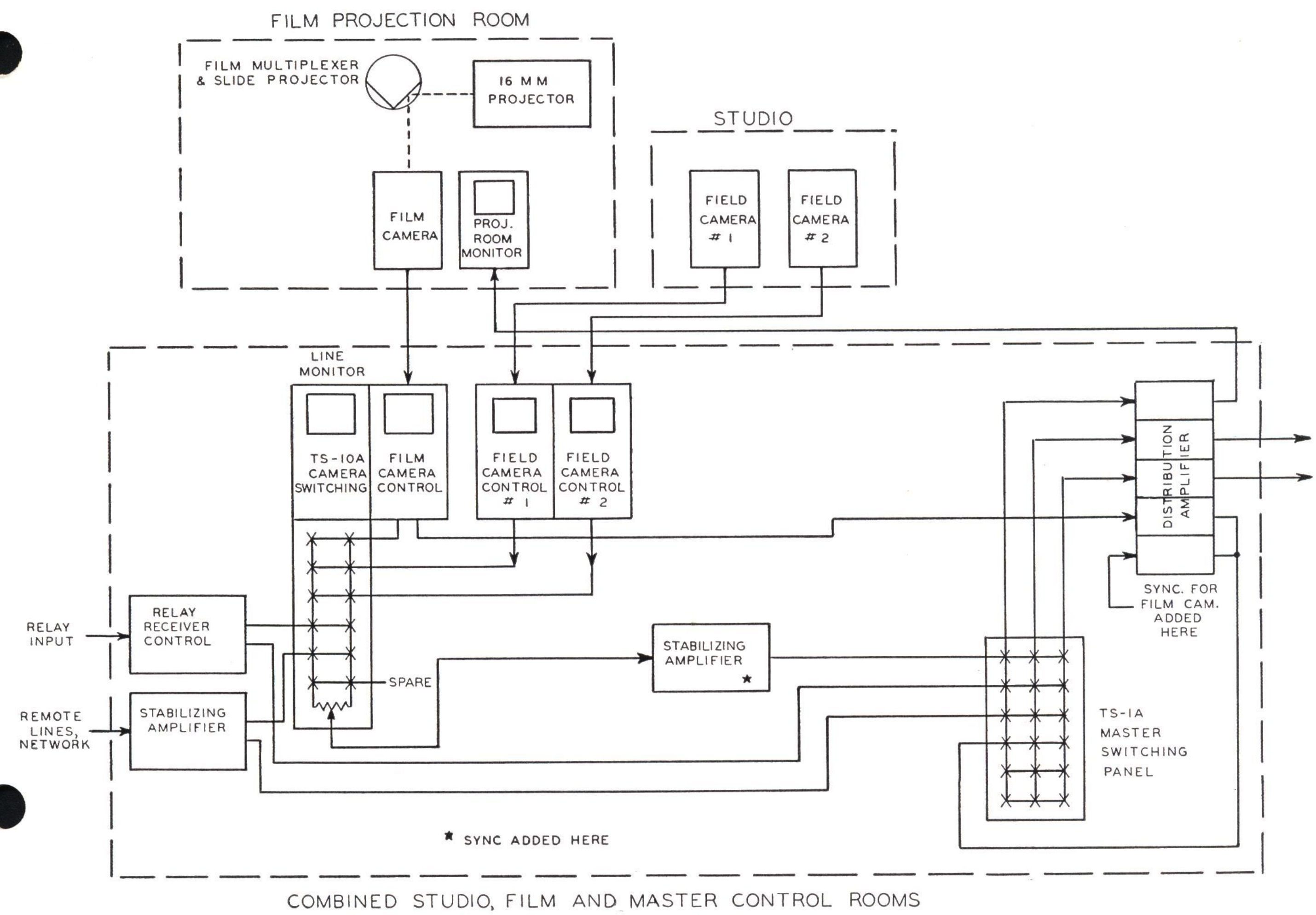


FIG. 17. (Above) Closeup of the TS-10A Switching System. With this system, the program director or the technical director can select the desired camera picture, or superimpose two pictures.

FIG. 18. Block Diagram of the major video items used in the Type B Small Station Layout. The TS-10A Camera Switching System is mounted in a section of the video console. The Master Switching Panel is rack-mounted.



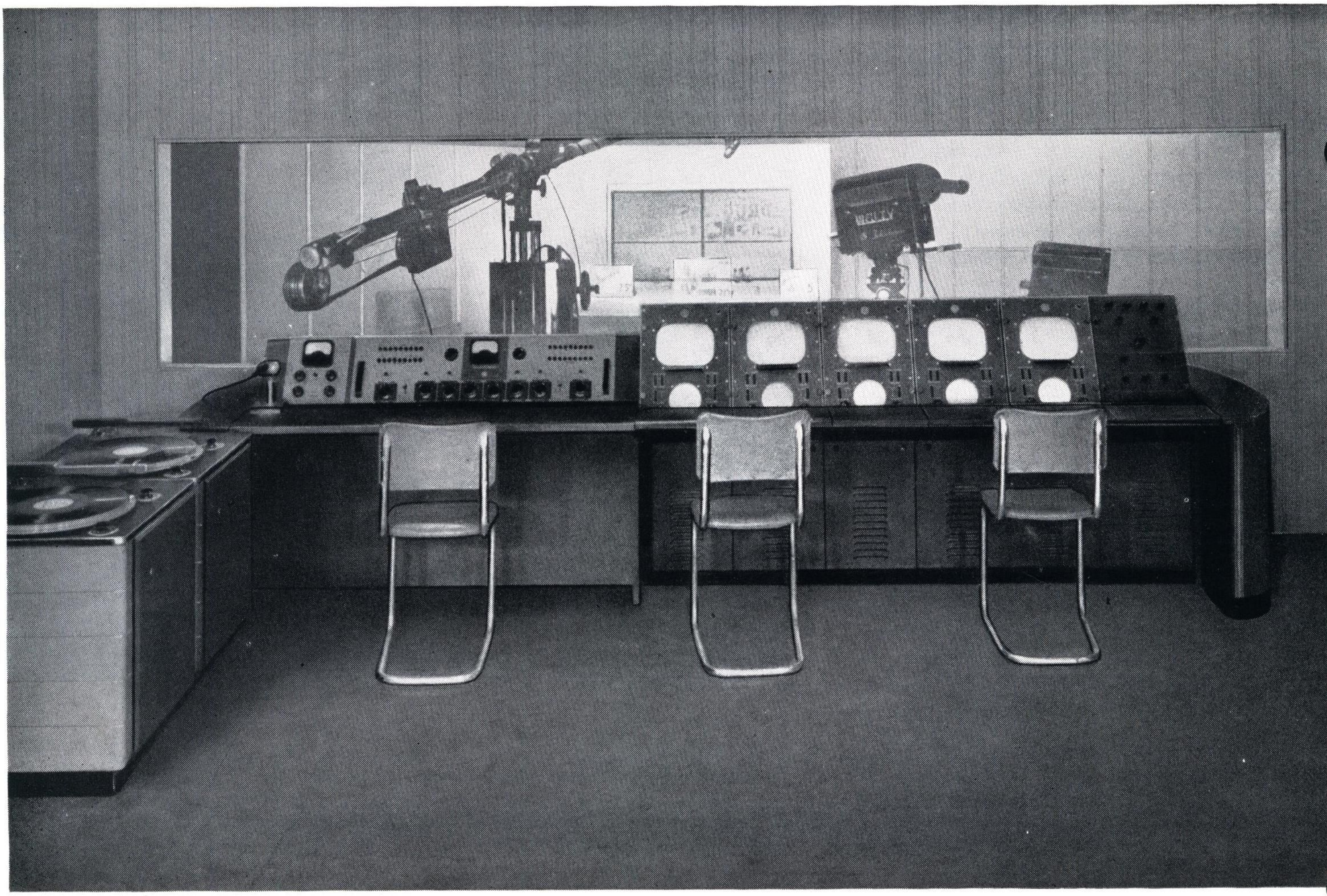


FIG. 19. Control Room of the "Standard" or Medium Size Type C Television Station. This station utilizes Studio-type Cameras and control room equipment. In this layout, field-type cameras and auxiliary control units are used for outdoor and remote pickups.

TYPE C LAYOUT FOR A STATION WITH INDEPENDENT FACILITIES FOR MAKING STUDIO AND FIELD PICKUPS

The Type C layout is suitable for the so-called "standard" or medium-size television station. In addition to field camera equipment, it includes studio type Image Orthicon Cameras in the studio, and standard RCA studio type control room equipment. Thus, studio programs can be put on even when the field equipment is at some remote location. It has other advantages over the small station layouts previously described, in that, (1) network shows, field pickups, and film shows can be run independently of the studio rehearsals and (2) studio and film productions can be combined with field pickups or other remote signals.

A typical floor plan for the Type C station is shown in Fig. 10. The layout includes a large live-talent studio, a projection room, a combined studio and projection control room, an announce booth, engineering workshop, and props and dressing rooms. The studio has adequate floor space to accommodate all scenery, property, floor lights, microphone booms, camera dollies, etc. Since there is only one studio in this type station, sufficient space is provided for setting up more than one scene. With sets at either end, for instance, the cameras in the center of the studio can shoot either way. The announce booth is provided with a microphone and video monitor. The video monitor displays a program line picture so that the announcer can see the scene he is commenting on.

In this layout, a program director works directly with one audio and one video operator. The program director is seated at the console located in front of a window looking into the studio, from where he does all the switching, and directs the show through the intercom system. Seated on the director's right is a video operator whose duty it is to get a technically good picture from each camera. The audio switching and control are done by the audio operator who sits to the left of the program director. Line amplifiers and power supplies for video and audio are located in equipment racks. These racks may be located in an adjoining room if desired. However, it is a distinct advantage to have them on the same floor level, to permit easy movement of video and test equipment between the areas.

Fig. 20 is a functional block diagram of the equipment used in the Type C layout. The combined studio, film and master control room has all the necessary monitoring facilities to monitor and cue the programs emanating from remote points or from both the projection room and the live-talent studio. It also has the switching facilities for routing any of these signals to the transmitter. Video control equipment consists of a TS-10A Switching System, two studio camera controls, one film camera

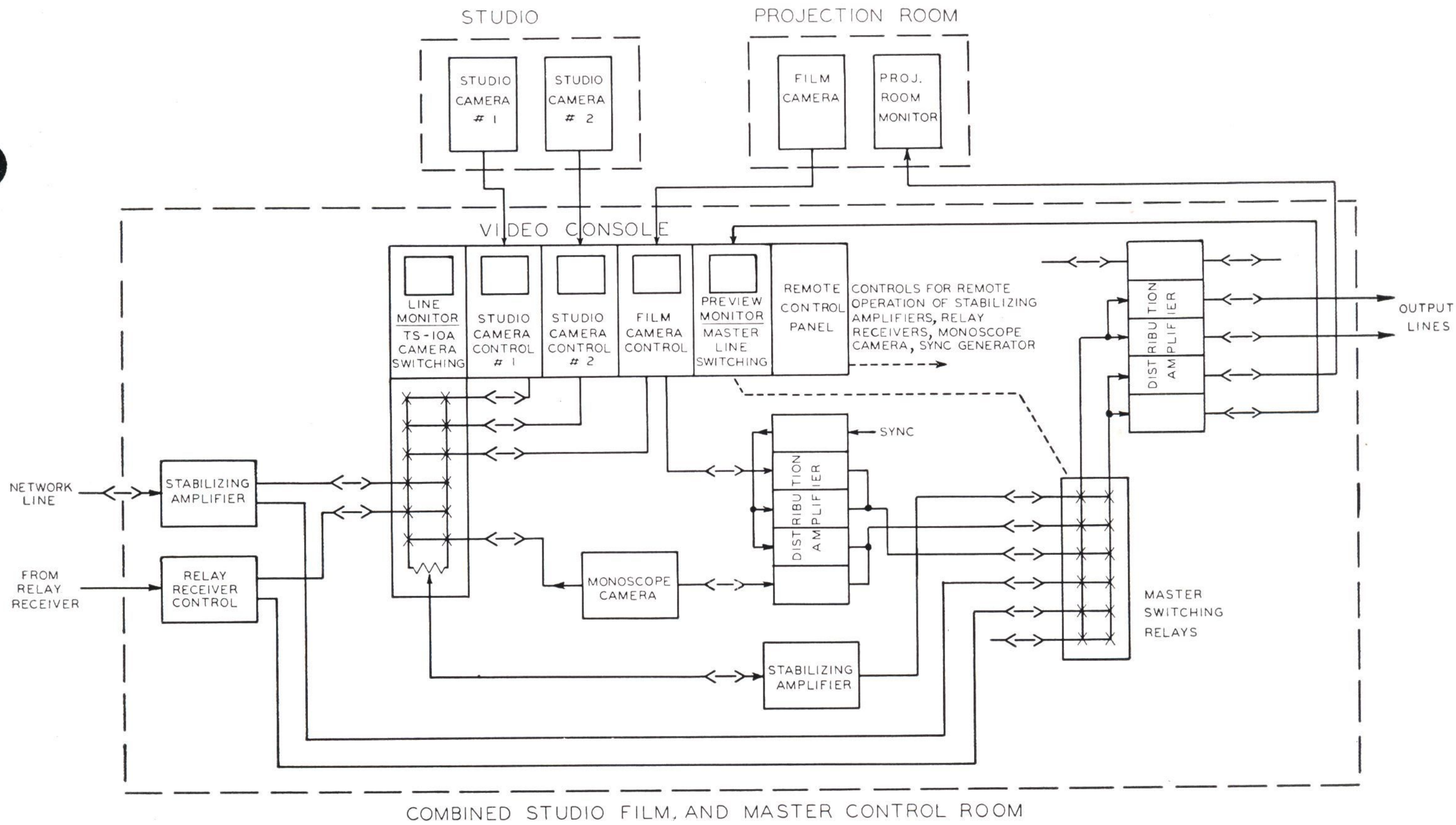


FIG. 20. Block Diagram of the Major Video Units Used in the Type C Station. Master switching in this layout is performed at the video console. Note use of video jacks for patching sources of signal into either the camera or master switching systems.

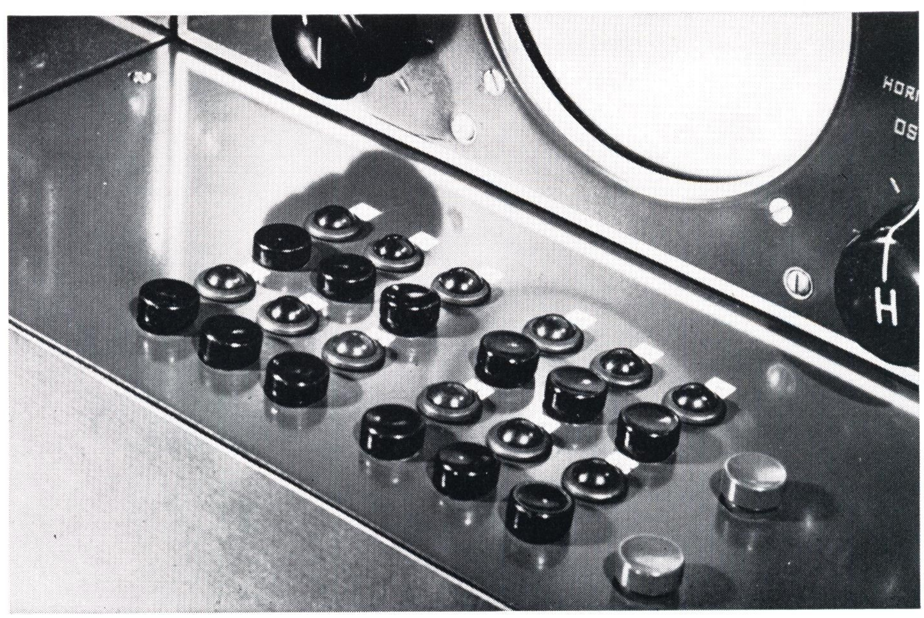


FIG. 21. (Right) Closeup of Master Switching Position. These pushbuttons, mounted in a console section, electrically operate relays rack-mounted in the control room.

control, a combined preview monitor and master switching section, and a remote control panel. The TS-10A Switching System serves for switching between the two studio cameras, film camera and remote incoming signals such as network or relay signals. The associated line monitor displays the signal going to master control. It also can be used to preview network and relay signals. The remote control panel is mounted in a console section at the right end of the video console. By means of the controls, the operator can make video and sync level adjustments on rack-mounted video amplifiers and sync insertion units.

Master Switching

The master switching panel is mounted on a sloping portion of the console desk top (see Fig. 21). It consists of a number of pushbuttons which electrically operate the rack-mounted master switching relays. It can accommodate six input lines and two outgoing lines. One outgoing line is connected to the preview monitor which provides for preview of any of the six inputs. The other outgoing line is connected into the transmitter. The operator, from his position at the console, can preview upcoming signals from all sources on his preview monitor. He can also switch any desired signal to the two outgoing lines. As can be seen by the block diagram, this layout employs a number of video jacks. These jacks, which are all rack-mounted on panels adjacent to each other, enable operators to patch in any signal either remote or local to either the camera switching system or the master switching system.

Elevated Platform Setup

Fig. 22 shows another possible arrangement for the equipment in the Type C control room. This arrangement requires another operator (technical director) at the video console. In this plan, the program director and audio operator are located on a platform (2 or 3 feet high) behind the console desk, where they can see all the video monitors as well as all studio action. The video operator is located at the console desk in front of the control room window, to the right of the technical director who has charge of all technical aspects of programming and who does all video switching.

In the platform arrangement, which actually can be used in any of the layouts described, it is important that the program director's desk be as close to the video console as possible to enable the director to look over the heads of the video operator and technical director. Therefore, the distance between platform and console should be kept to a minimum (2 feet, if possible). This, combined with the height of the program director's position gives him a view of the studio and the video monitors. Station layouts Types E and F described later, however, make use of the RCA Director's Console which provides both preview and line monitors in front of the director, and thus obviates the need for a platform arrangement.

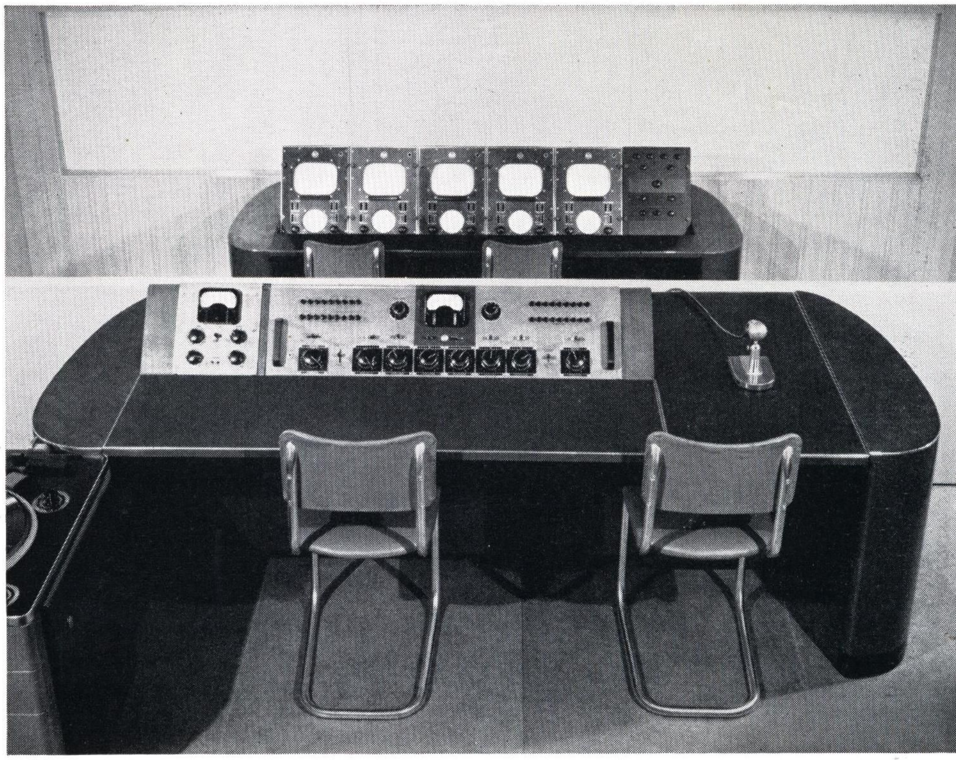


FIG. 22. Some broadcasters prefer to locate the program director and audio engineer on an elevated platform to provide them with a better view into the studio. Shown on the platform in this photo is the audio control console, plus a desk section providing space for the program director and his scripts.

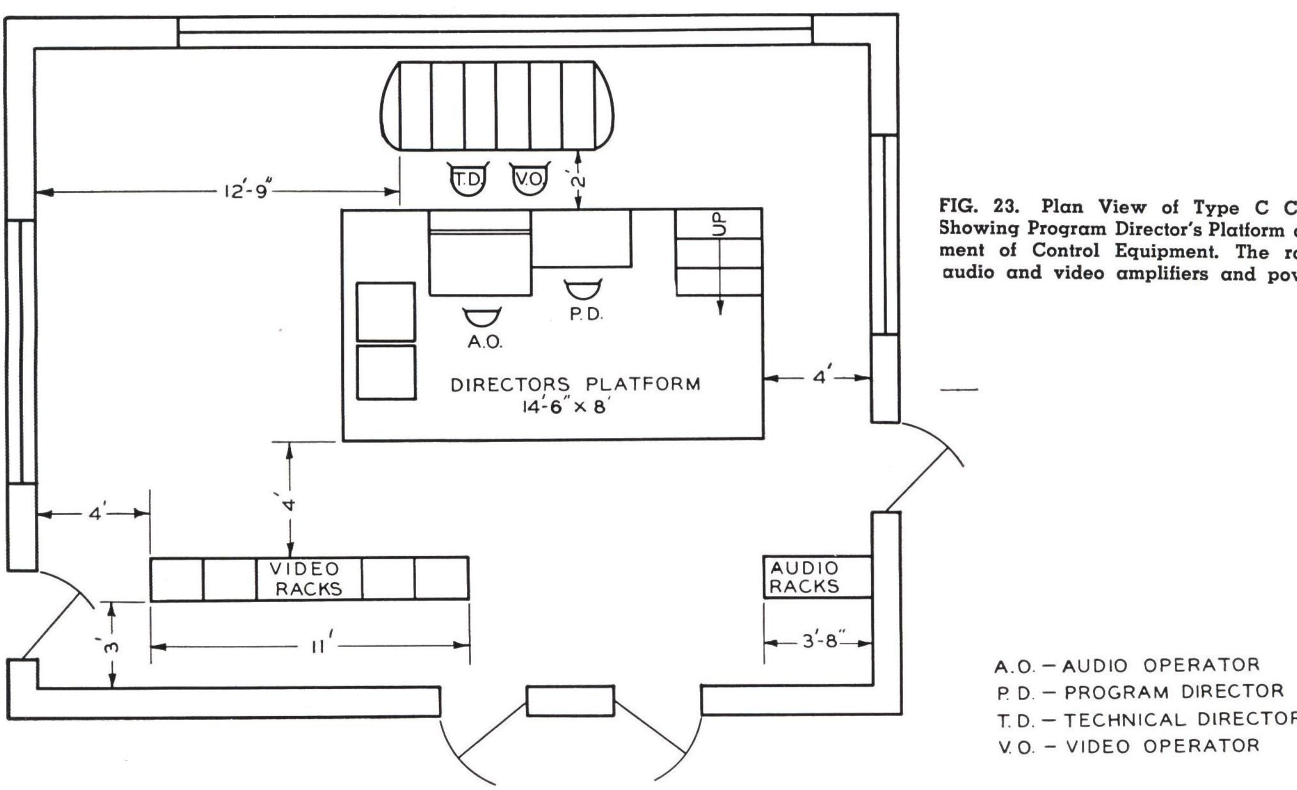


FIG. 23. Plan View of Type C Control Room Showing Program Director's Platform and Arrangement of Control Equipment. The racks contain audio and video amplifiers and power supplies.

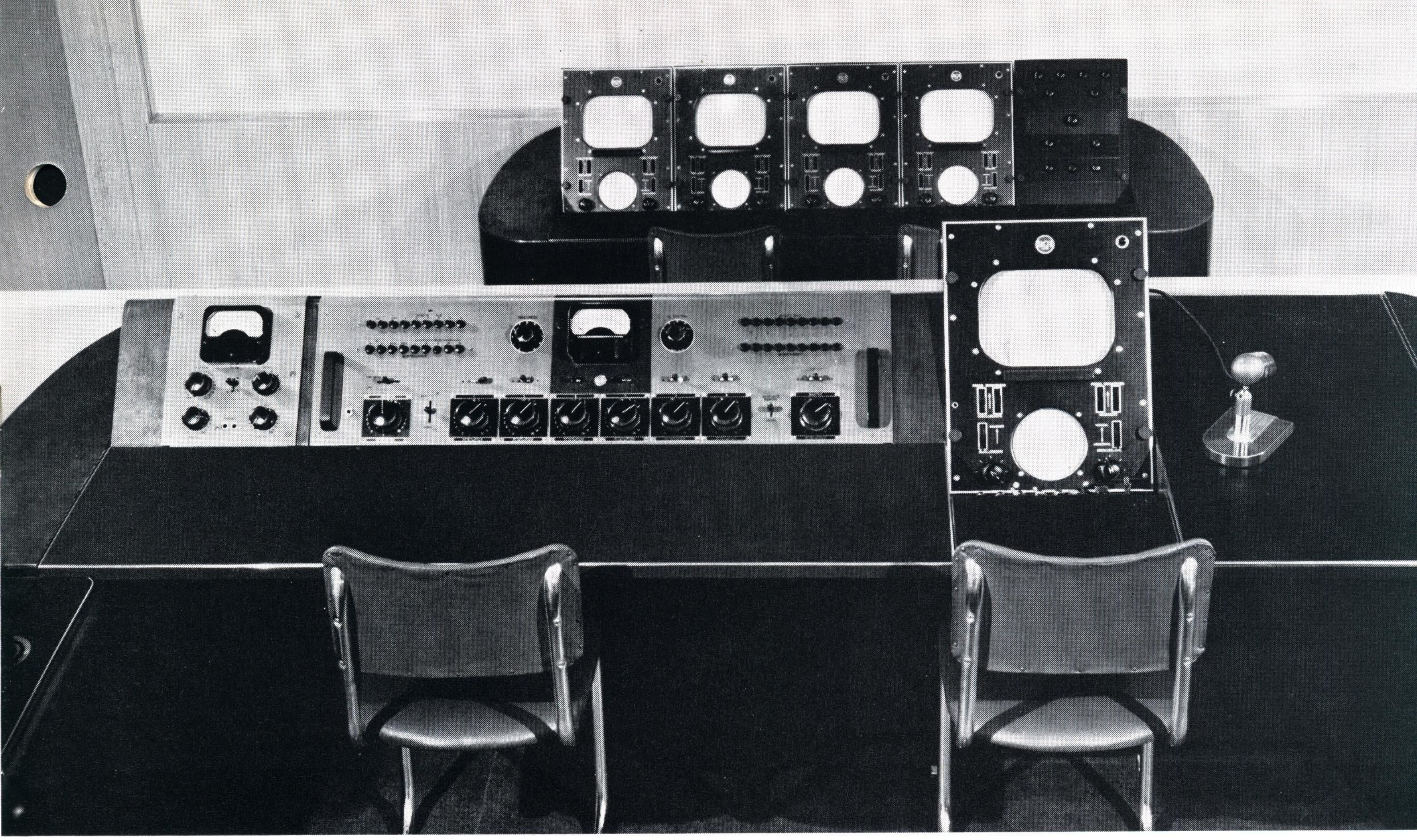
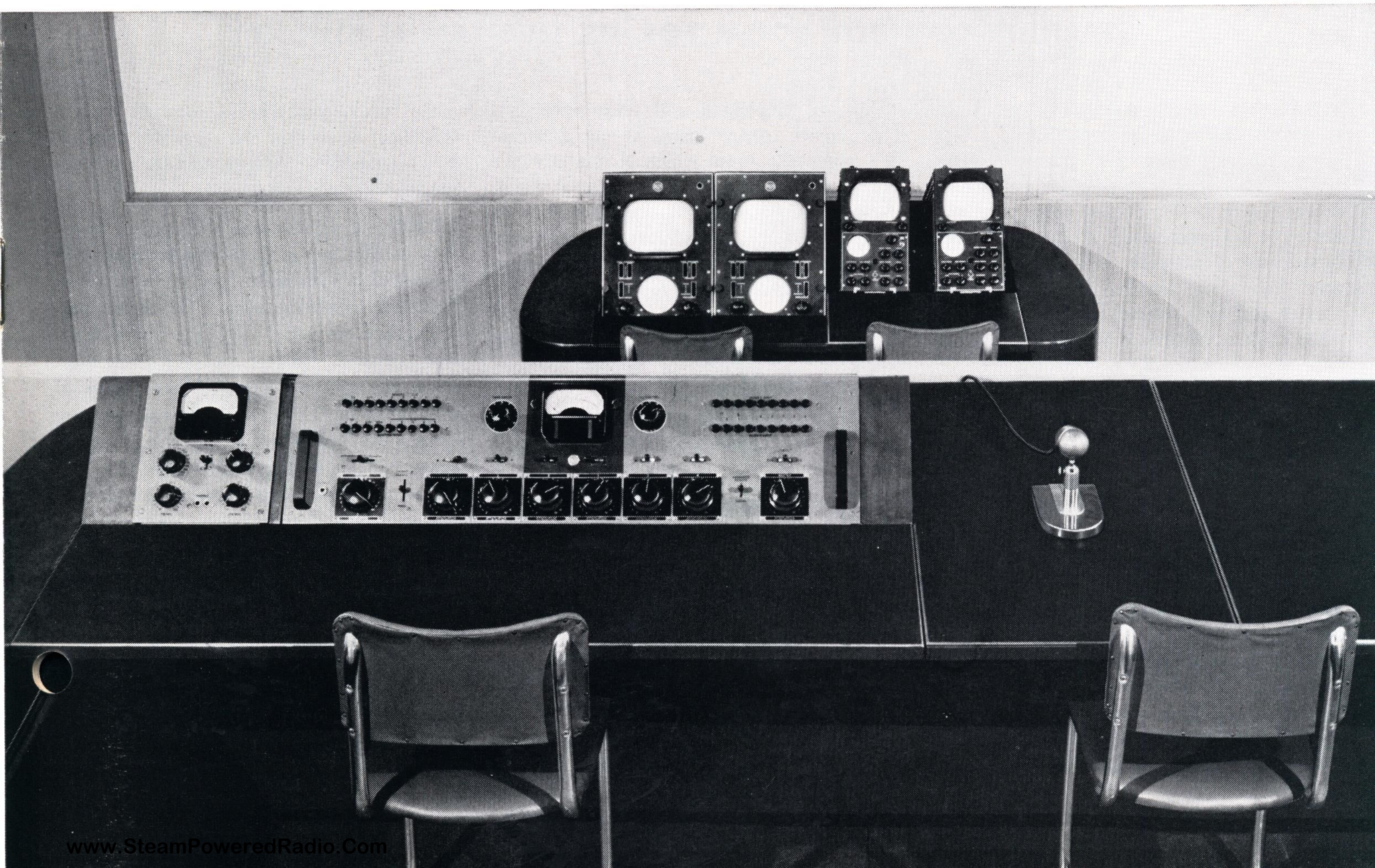


FIG. 24. To provide the director with closer supervision over video switching operations, the TS-10A Camera Switching System can be located on the platform with the audio console, as shown above. Platform setups are possible with any of the equipment layouts described. Photo below shows an arrangement for the Type B station previously described.



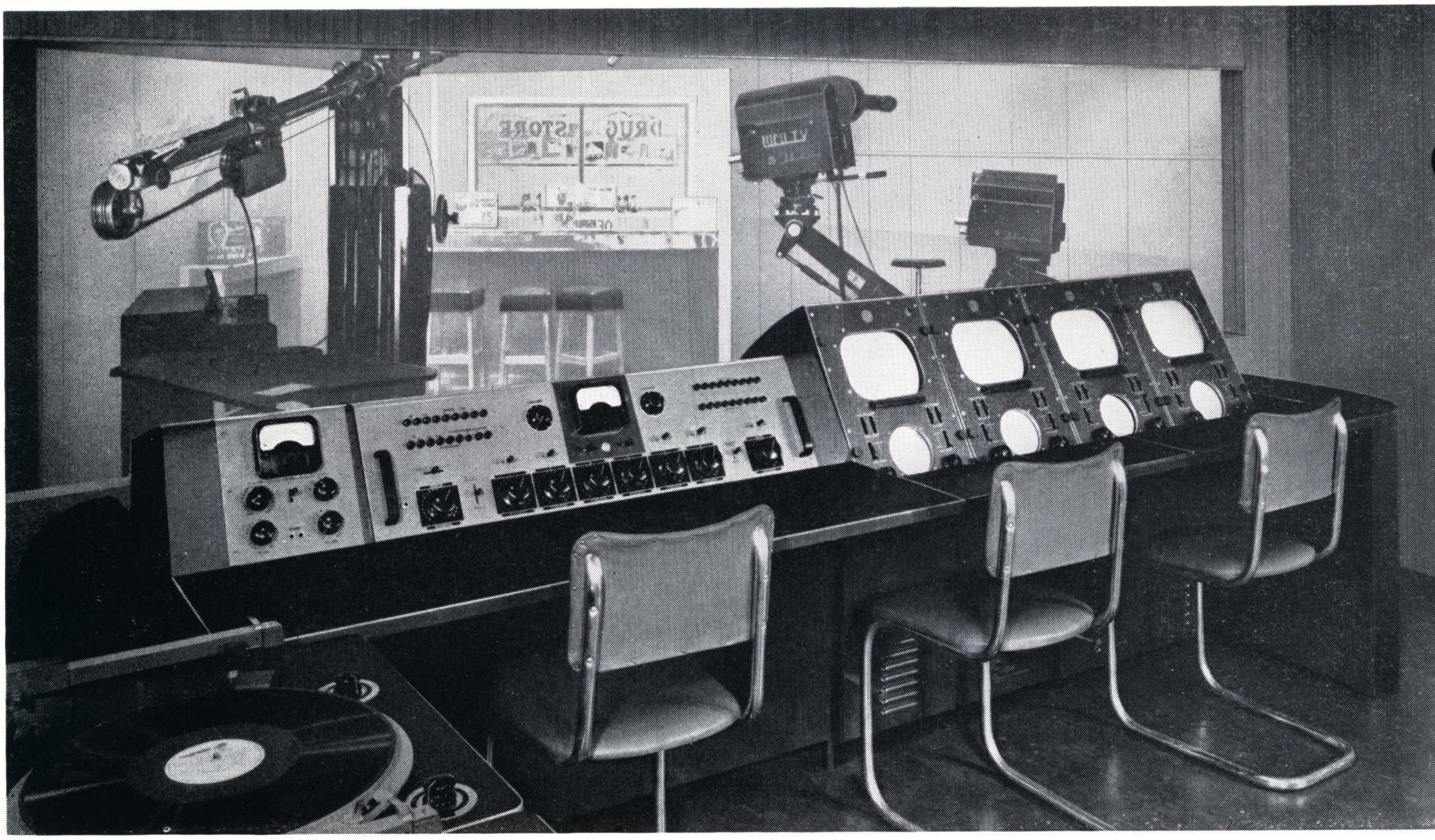


FIG. 25. Studio Control Room of Type D Layout. This layout has a separate control room for the live talent studio, which permits camera rehearsals while remote pickups, network or film shows are being broadcast through master control.

TYPE D LAYOUT FOR A STATION PROVIDED WITH A SEPARATE CONTROL ROOM FOR ITS LIVE-TALENT STUDIO

A further refinement in the design of the television station is the provision of a separate control room for the live-talent studio. This makes it possible for studio rehearsals to be conducted using the separate control room, while at the same time, broadcasts of network, relay or film programs are being handled in the combined master and film control room. Thus complete camera rehearsals of studio programs can be run without interrupting regular program output of the station.

The studio control room in this case employs a four-section video console comprising a TS-10A Camera Switching System, two studio camera controls and a preview monitor. The combined master and film control room consists of a five-section video console which employs a TS-10A Switching System (for switching and lap-dissolving between the two film cameras), two film camera controls, a transmitter line monitor, a preview monitor and a console section containing the master switching pushbutton and a control panel for remote control of the gain and other functions in stabilizing amplifiers and relay receivers. The remote control panel is not a necessity, since the units which it controls are usually rack mounted in the control room. However, remote control of these units permits a single operator to make adjustments at the console while watching the picture on the adjacent preview monitor. Also, this system of remote control can be extended to include stopping and starting of film projectors, adjustment of monoscope cameras and shifting of sync generator phase, thus permitting many operations to be carried out from one point in the control room.

A typical arrangement of the equipment in the Type D studio control room is shown in the photo above. This control room is a complete unit capable of putting on live-talent shows, film shows, network programs, outdoor pickups, and slides. The flexible system of jack panels in the master control room enables any of these signals to be patched into, and thus be controlled from, either the studio control room or master control. Another feature, the use of preview relays (controlled from a switching panel on the preview monitor desk) provides preview pictures of any one of these signals.

Using the studio and this control room, both production and technical aspects of the television program can be carried out. The photo shows positions for three operators: left to right, they are audio operator, program director and video operator. Here, the program director has charge of all camera switching which he can perform by use of the TS-10A switching system in the console section before him. The picture appearing on the monitor in this console section is that from the camera which he selects for program line. The picture appearing on the monitor in this console section is that from the camera which he selects for the program line. The video operator's duty is to keep each of th cameras at the proper contrast and brigh ness levels and in general maintain good picture quality. Preview pictures from each camera, of course, are viewed on the two

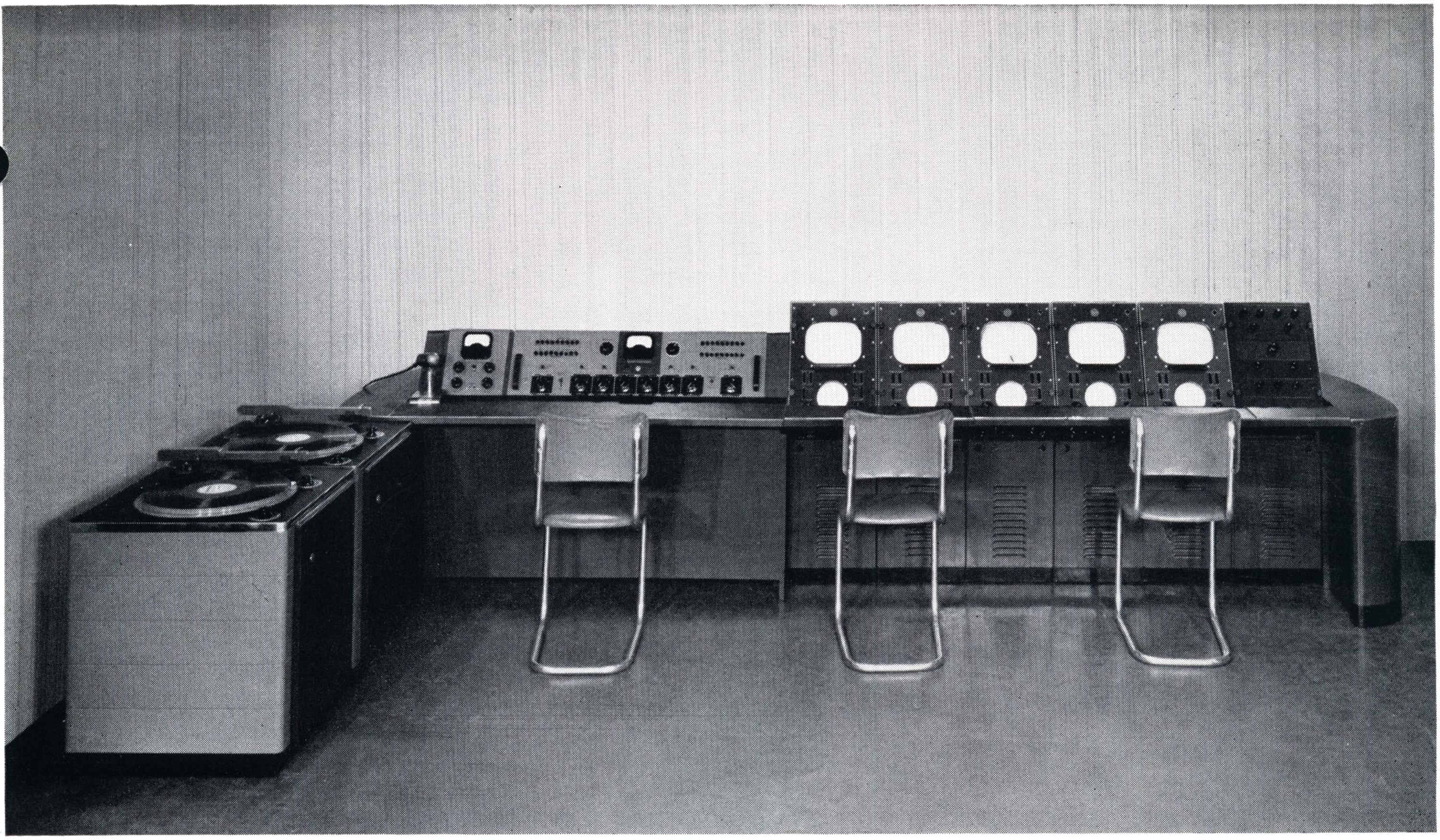
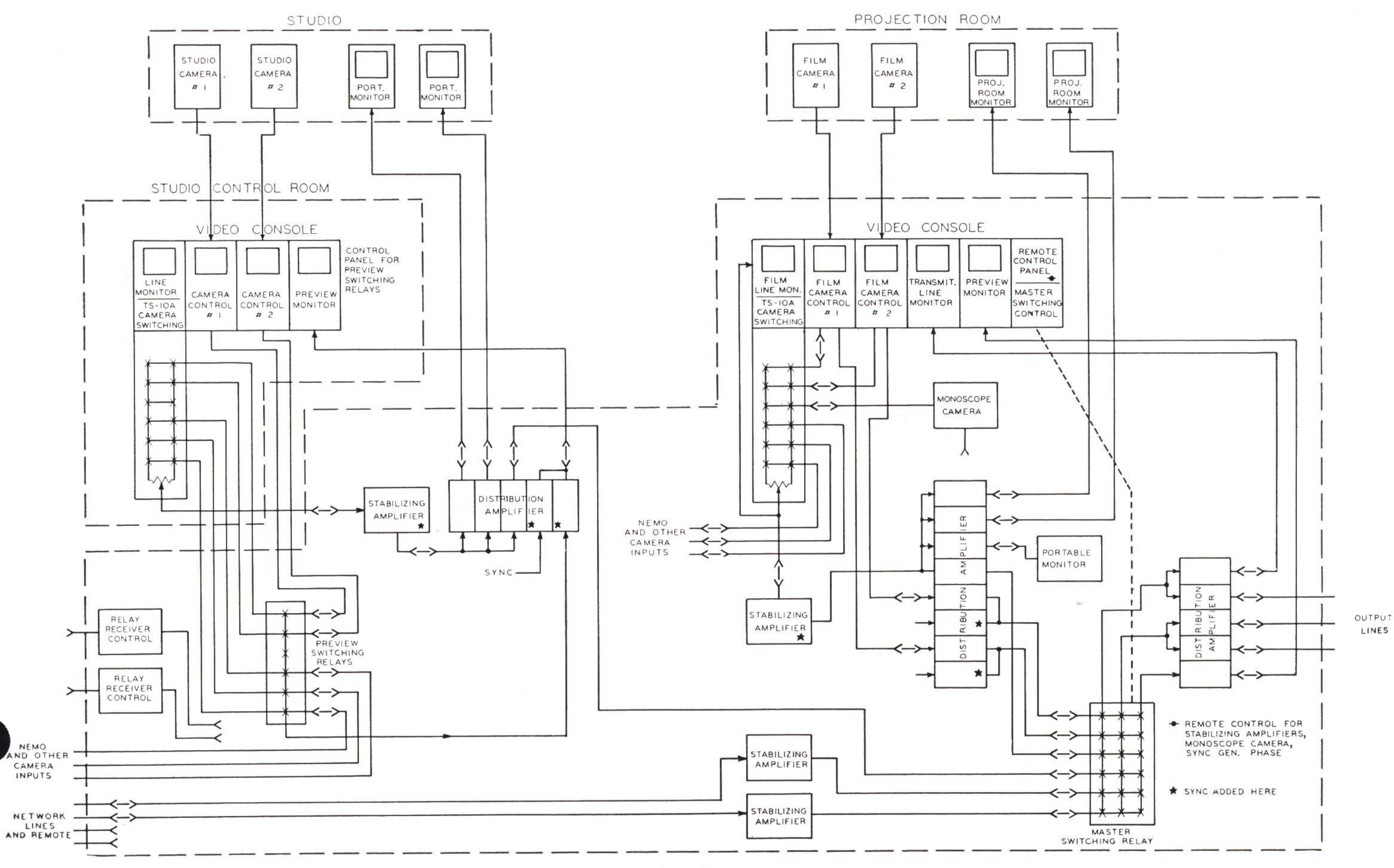


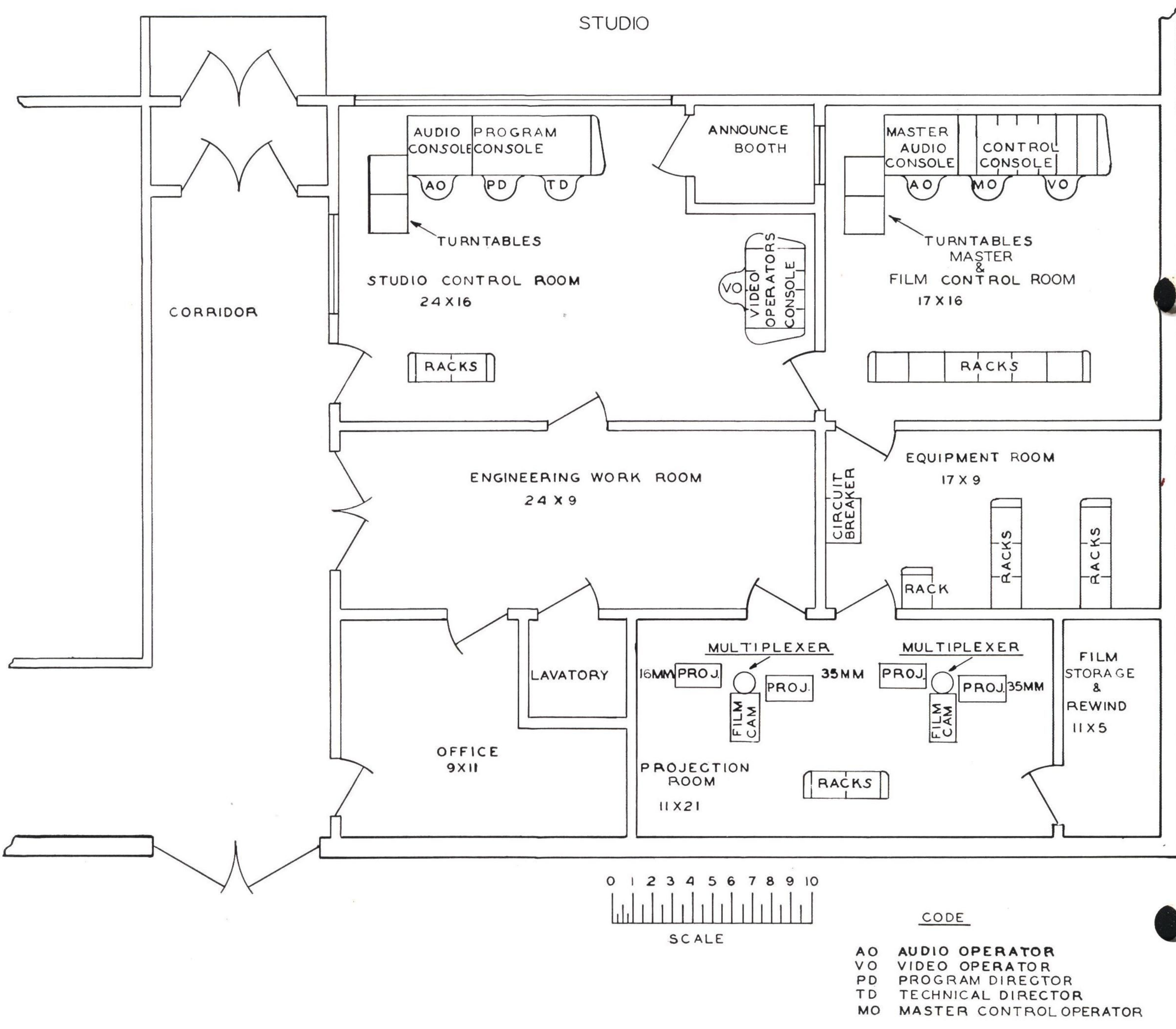
FIG. 26. (Above) Combined Film Control and Master Control Room of the Type D Station. Audio and video console handles output from film projection room, network lines and microwave relay. **FIG. 27.** (Below) Block Diagram of Video Units in Type D Layout. The video console in each control room contains a TS-10A Camera Switching System. Through a rack-mounted system of jacks, any source of signal can be fed to either control room for cue or insertion into the program.



camera control monitors in front of the video operator. The preview monitor at the right end of the console displays the signal (relay, network, or film) which could be broadcast during studio rehearsals, or switched in as a part of the studio program. Thus, the preview monitor provides a means for cueing the studio show into the program line, when necessary, as well as previewing external cameras to be switched in. Use of patch cords and jacks in master control makes it possible for the program director from his position in the control room to switch films in as part of a studio show. Films and slides are frequently used during station identification breaks.

The schematic arrangement of the entire video switching system is shown in the block diagram of Fig. 27. Video signals from the studio cameras, film cameras and monoscope test camera are fed to their respective switching systems in the studio control room and in the master and film control room. Output from the studio control room as well as from the projection room is fed to the switching system in the master and film control room, where the desired program signal can be selected. As in the C type layout, pushbutton operated relays are used for master switching. The master switching system in this layout, however, has an additional bank of relays, which provides an additional output line. These output lines can feed to the transmitter room, to clients' viewing rooms or even to a network line. Switching between film cameras is performed by a TS-10A Camera Switching System identical to that used in the studio control room.

FIG. 28. Partial Floor Plan for the Type D Station. The equipment arrangement shown is for the Type E station described on the following page. The floor plan will serve for both D and E Type layouts. Note location of announce studio so that visual cue can be taken from either control room.



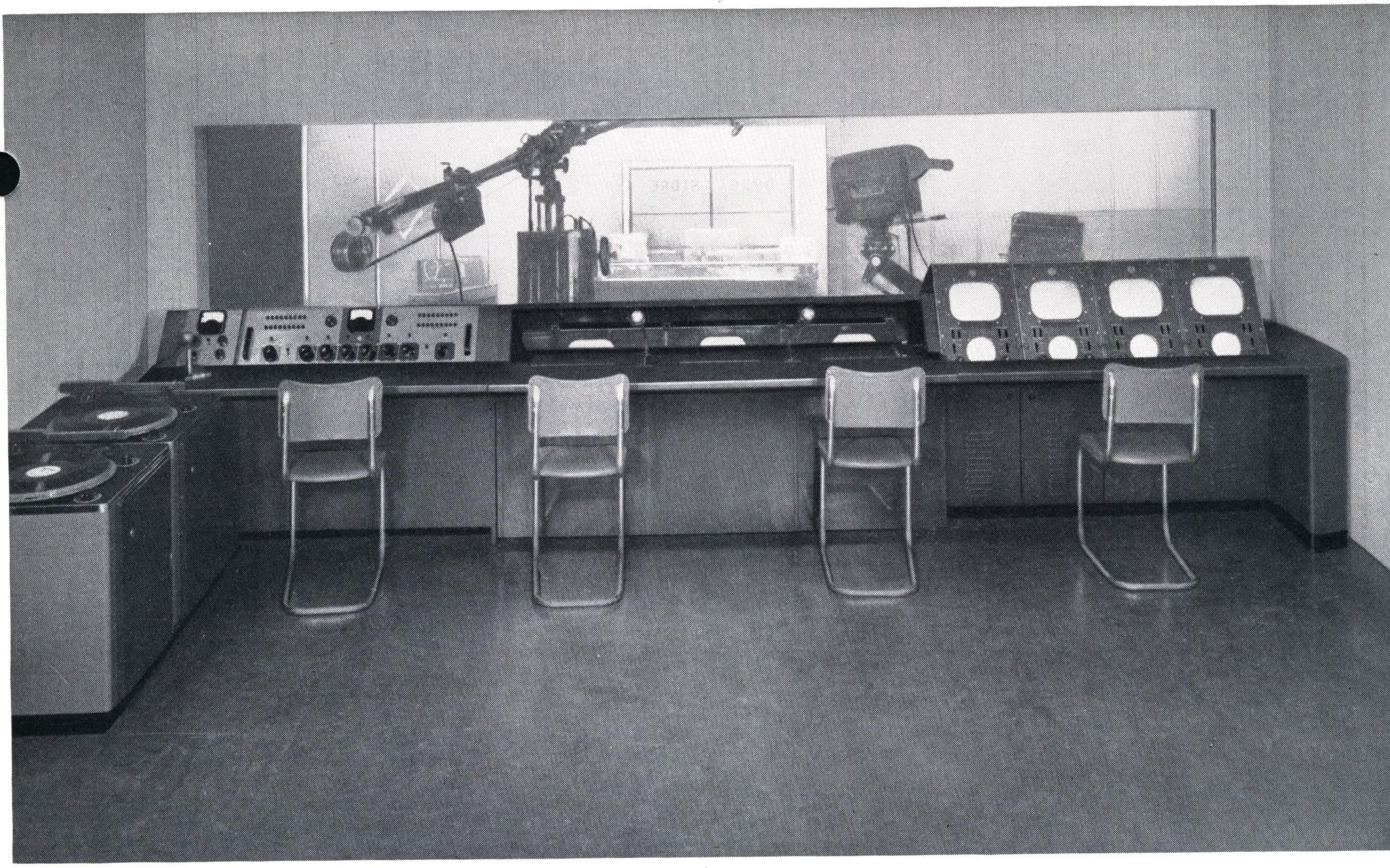


FIG. 29. Studio Control Room of the Type E Layout. This layout employs two control rooms, and features the utilitarian Program Director's Console (center), described in the text. Video Console at right displays pictures from each of three Studio Cameras plus picture on studio output line.

TYPE E LAYOUT FOR A STATION SIMILAR TO TYPE D, MODIFIED FOR FURTHER FLEXIBILITY IN ARRANGEMENT AND UTILITY

The fifth type of television station is the Type E arrangement. Like the Type D previously described, Type E employs one live-talent studio, a studio control room, a projection room and a combined master and film control room. It differs from the D layout in that an RCA Program Director's Console (center in photo above) replaces the TS-10A Camera Switching System in the video console. The director's console has a pushbutton switching panel which operates rack-mounted relays for camera switching. It also has large picture monitors which provide the director with preview and line pictures. Another difference in the layout is the use of three studio cameras instead of two: Space in the video console section previously occupied by the TS-10A Camera Switching System now houses the camera control chassis for the additional camera. As in layout D, a TS-10A Camera Switching System is used for switching between two film cameras and remote signals. A functional block diagram of the layout is shown above.

Use of electrically-operated relays for studio camera switching adds to the layout flexibility of the system, particularly as to the locations of the control rooms. This becomes even more important when more than one studio is provided. Delay compensation for the different studio runs is simpler when all camera switching is done at one central location.

Camera Relay System

The camera switching system used here is designated as the Type TS-20A Remote-Control Studio Switching Equipment. Basically it consists of the program console with its monitors, banks of momentary-contact pushbuttons and tally lights, and fader controls mounted on the console desk, plus associated rack-mounted equipment such as relay panels and fader and stabilizing amplifiers. As can be seen in the drawing, signals from all cameras including monoscope test cameras, network and relay signals, when patched into the relay system, can be switched to master control. These local signals can also be lap-dissolved and faded.

The Program Director's Console is another outstanding feature of this layout.

This console, which is illustrated in Fig. 30, is designed expressly for use by program and technical directors in supervising studio programs. The console is only 37 inches high (which provides full view of the studio). It can accommodate as many as five 10-inch monitors, which are recessed below the desk top to prevent direct light from striking the screens. These five monitors can provide the directors with preview pictures of all cameras if desired, plus pictures from a network signal and the program line. The photographs show the arbitrary use of three monitors in the console: a preview monitor which displays the picture produced by any one of the three cameras; a line monitor which displays the signal switched to master con-

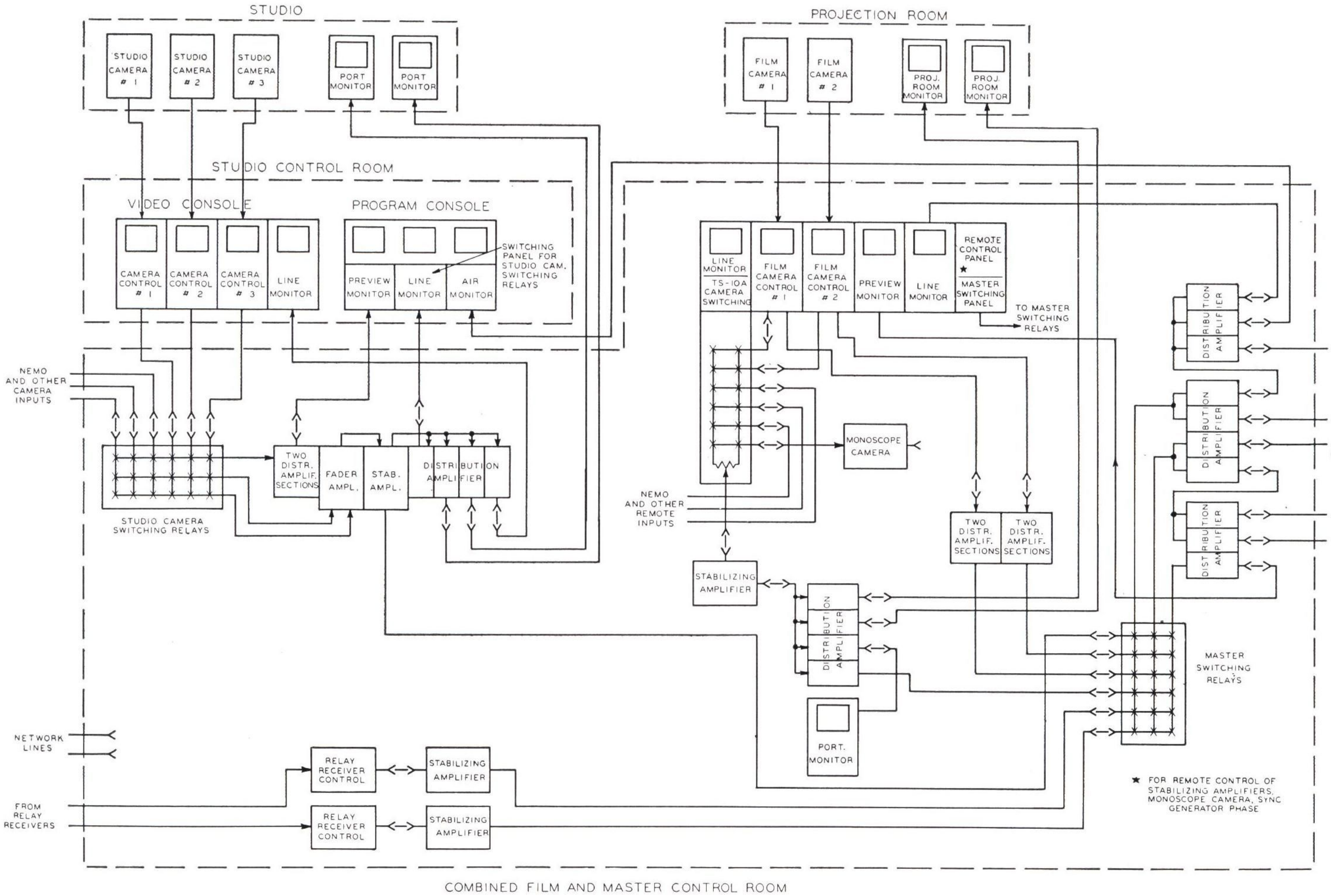


FIG. 31. Block Diagram of the Type E Layout. In this layout studio camera switching is performed at the program director's console. Pushbuttons mounted on the console operate relays rack-mounted in the control room.

trol; and an "air" monitor which shows the picture on the output line of the master control room.

The Director's Console is unique in that the program and technical directors have large bright pictures of the program directly before them and need not depend on their ability to see the monitors in the video operator's console, which may be located several feet away. In this setup, the technical director would ordinarily do the necessary switching at the request of the program director. Both directors can use the intercom and talkback system, built into the console, for communicating with production and technical personnel at the cameras and in the control room, projection room, dressing rooms, etc.

Use of a number of distribution amplifiers on the outgoing lines of the master switching system provides in this layout three independently switched output lines from master control. These output lines may be used to feed the transmitter room, clients' viewing rooms, and one or more networks lines.

FIG. 30. Type TC-5A Program Director's Console. This modern console provides the program director and technical director with pictures of the scenes being picked up by the individual cameras, from which the program signal can be selected.

TYPE F LAYOUT FOR A STATION UTILIZING TWO (OR MORE) LIVE-TALENT STUDIOS

Type F is a complete equipment layout for a "master" television station with facilities for the production and broadcasting of all types of television programs. It includes facilities for simultaneously originating and rebroadcasting different network shows. Such a station is usually provided with: (1) a film projection room with a projection control room; (2) two or more studios with individual control rooms, so that live-talent rehearsals can be carried out while studio programs are on the air; (3) facilities for picking up outdoor events; and (4) a master control room in which the desired program material can be selected from any of the above mentioned sources.

The Type F layout does not represent the ultimate as far as a station layout is concerned; but it does illustrate the schematic arrangement of the equipment required for a station employing two studios and providing the facilities needed for the master type station. This layout is designed to furnish a high degree of flexibility in programming. Facilities are provided to handle live-talent shows, films, outdoor pickups and remotely originated shows, while rehearsals are in progress at the station. It consists of a large studio (Studio A) with its own control room; a smaller studio (Studio B) with its own control room; a projection room with its own control room; and a master control room. Each of the studios is a complete unit, capable of producing live-talent shows. Output from film control and from each of the studios, as well as signals from networks and remote pickups are routed through master control where the signal to be fed to any one of the outgoing lines can be selected. The flexible system of jack panels permits remotes, film and other studio outputs to be switched at either of the studio control rooms as well as at master control.

Film Facilities

The projection room houses the film projectors, film cameras, and slide projectors. Three film cameras can accommodate as many as six projectors, using the Type TP-9A Multiplexer, a mirror device previously described. However, as suggested in the drawing, a more utilitarian arrangement might be to set up one film camera which will handle slides exclusively, and provide four film projectors (two 16mm

FIG. 32. One of the Studio Control Rooms in the Type F Station. This type station employs two or more studios each with similarly equipped control rooms. Several other physical arrangements of the unit-built control equipment are possible.

and two 35mm) to be used with the other two film cameras. However, the Multiplexers can be obtained equipped with slide projectors so that it is possible to insert slides into any camera chain even though it has been set up with two motion picture projectors.

The switching system for the film camera control room is a relay switching system of the same general type used in the studio control rooms. The pushbuttons which operate the relays are mounted on the desk section of the video console located in the film control room. The system is capable of switching and fading between any of the three film camera outputs. Jack panels located in master control also provide for patching in remote signals or signals from other cameras to this switching system. In addition to the above, the output of each film chain is connected to the master switching system through a distribution amplifier (where the sync signal is added). This makes it possible to put on film shows or preview a film in a client's room without use of the camera switching system.

Remote Signals

Facilities are available for handling a number of remote signals by telephone company lines and by microwave relay. Stabilizing amplifiers are available on the same jack panels as the incoming signals so that they can be connected into the circuits. The stabilizing amplifiers are designed to set the proper synchronizing-to-picture ratio and to improve the quality of the synchronizing signal of incoming remotes. The stabilizing amplifier utilizes clamp circuits to remove hum, bounce, and other line disturbances.

The relay receivers and the stabilizing amplifiers are rack mounted in the master control room and their remote controls are brought to a console section for convenience in setting up and operating the equipment. Each of these pieces of equip-

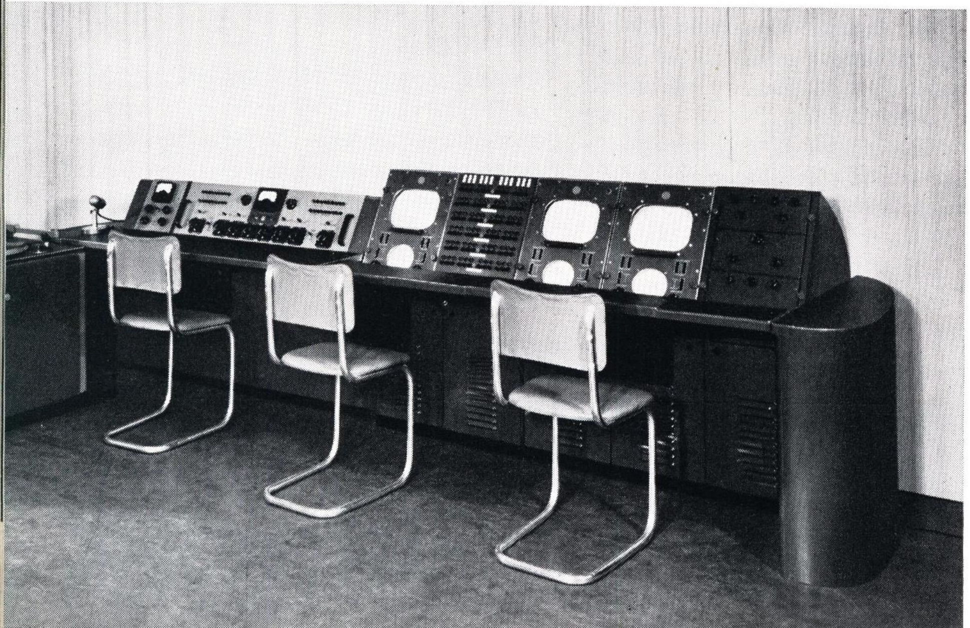
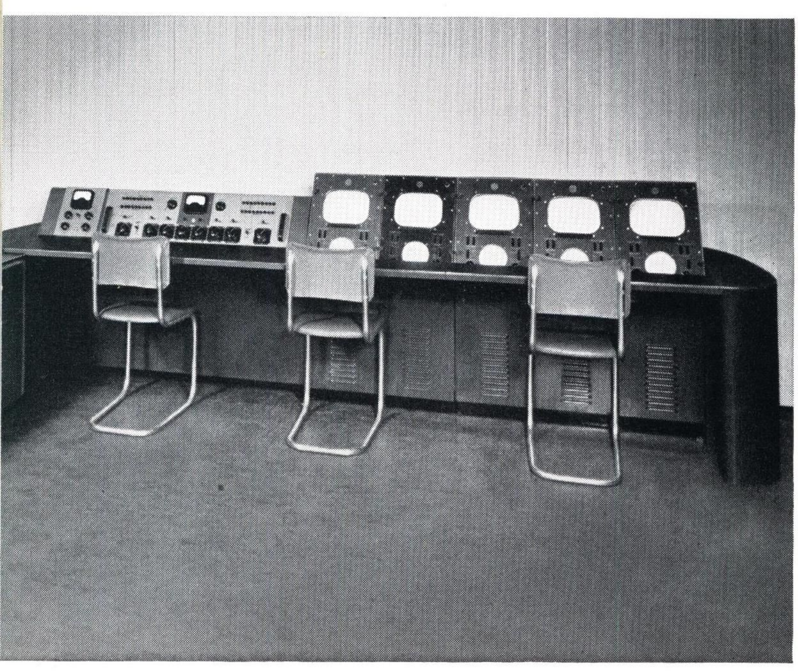
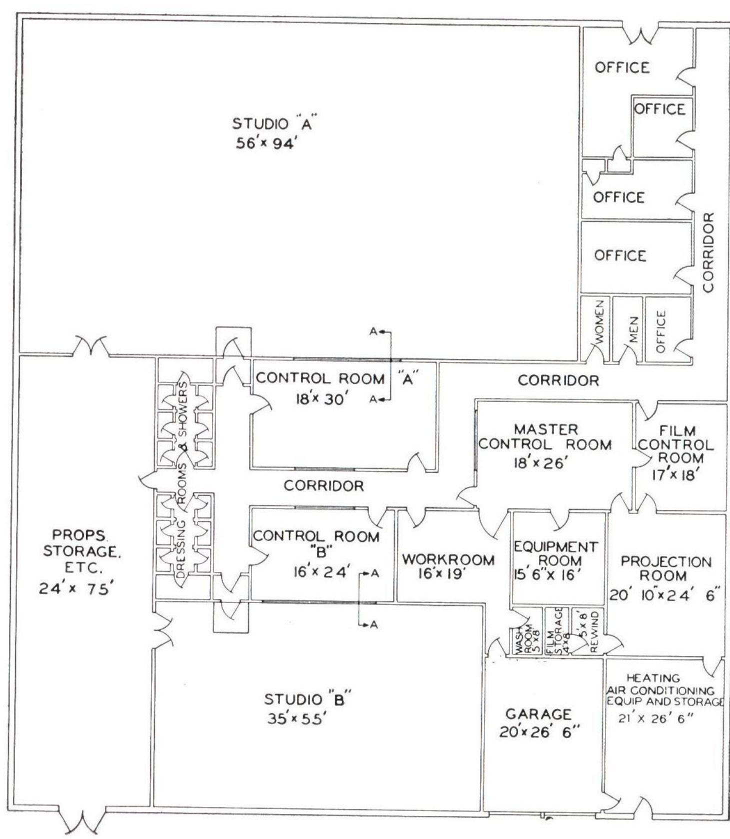


FIG. 33. The Type F "master" station employs separate control rooms for its studios, projection rooms and for master control functions. Above photo shows the master control console; below is the film control console. Diagram at right is a partial floor plan of the station.





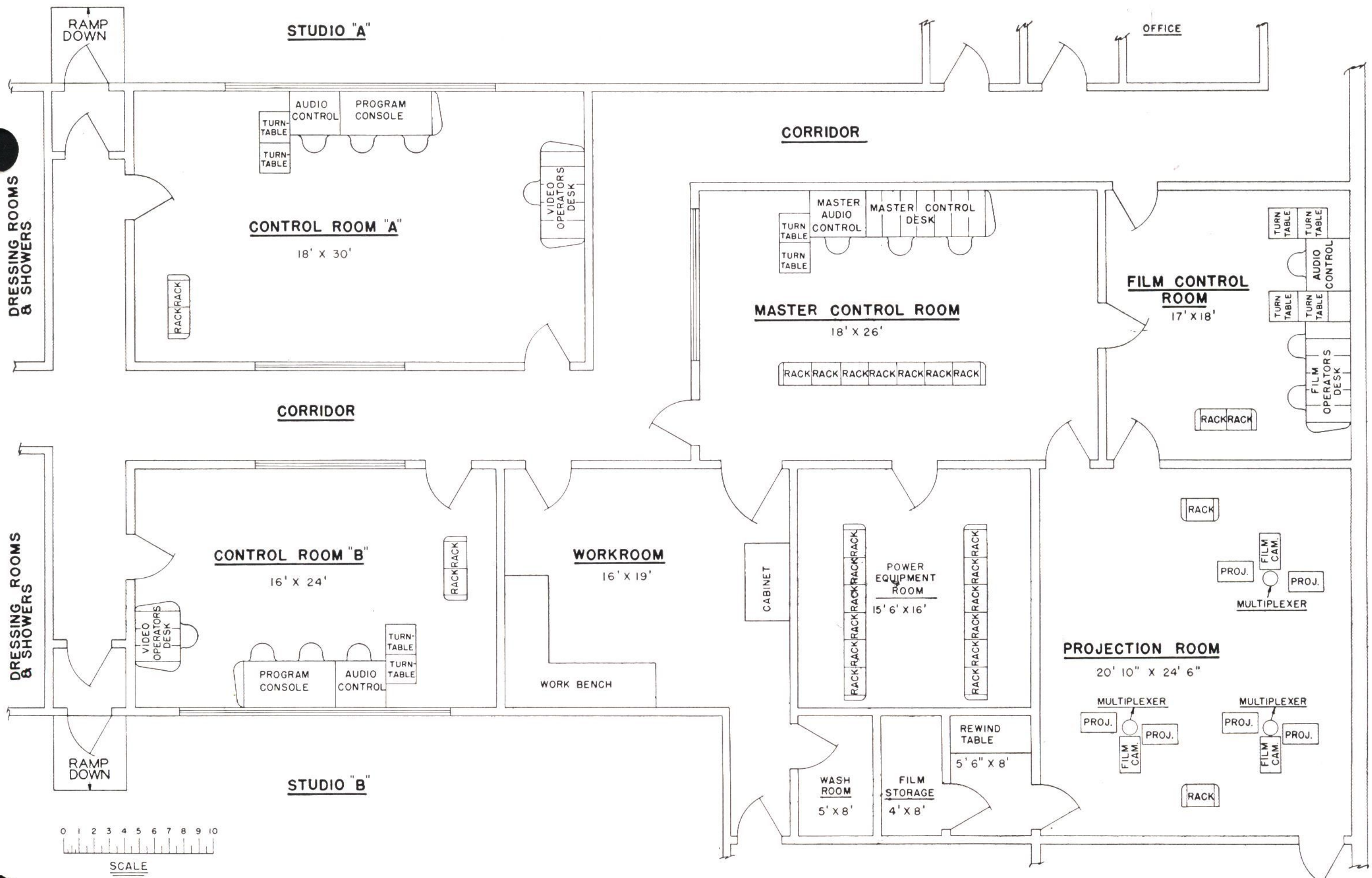


FIG. 34. Diagram showing Layout of Control Rooms and Arrangement of Equipment for the Type F Station.

ment has two outputs available at jack panels so that signals can be fed to the master switching system or to the studio camera switching system independently.

Master Control Room

All switching for the station (including studio camera switching) is accomplished by relays located in the master control room. Video signals, local and remote, are fed to jack panels where they can be connected into any part of the system. All camera signals are fed to a jackboard where they are normally connected through to the corresponding video switching relays. These relays are controlled from pushbuttons located in the various switching positions. Each studio control room has associated with it three banks of interlocked relays, two for the fader amplifier and one for the preview monitor.

The master control switching selects the desired composite signal for transmission. This system consists of six banks of twelve interlocked relays each, thus providing for six output circuits and up to twelve input circuits. Two of the output circuits are fed to two preview monitors located in the master control console. The four remaining lines can be switched independently to any of the twelve incoming signals. This provides for four separate programs to be transmitted at one time. Each of the four outgoing program signals can be connected to distribution amplifiers to give additional outgoing lines to feed clients' rooms, viewing rooms, offices, studios, etc.

The master control console itself consists of five video console sections. Two of these contain the two preview monitors, one contains the on-the-air monitor, one the switching controls, and one contains the remote controls for stabilizing amplifiers, relay receivers, and sync generator phasing controls.

Two synchronizing generators (one a spare) are provided in the master control room with a switch to select the desired generator for use. This then feeds distribution amplifiers to distribute the blanking, driving, and synchronizing signals to the various parts of the system. In case the differences in physcial separation of the master control room and the individual studio control room is great, delay compensation can be inserted between the sync generator and the various distribution amplifiers.

This overall system is extremely flexible as it provides numerous combinations of camera facilities for programming and rehearsal. Cameras and remotes can be patched into any studio switching system so that the program director at his console in a studio control room can have complete control over the switching of any studio cameras, film cameras, or remotes that he may require to make up a given program. A complete film program can be run entirely by master control room when so required. In this way the facilities of an individual studio may be used for rehearsals while another studio or film is put on the air. One film chain may be used for a program while other film is previewed in a client's room without interference. Thus almost any combination of facilities may be used to suit the particular requirements that may arise.

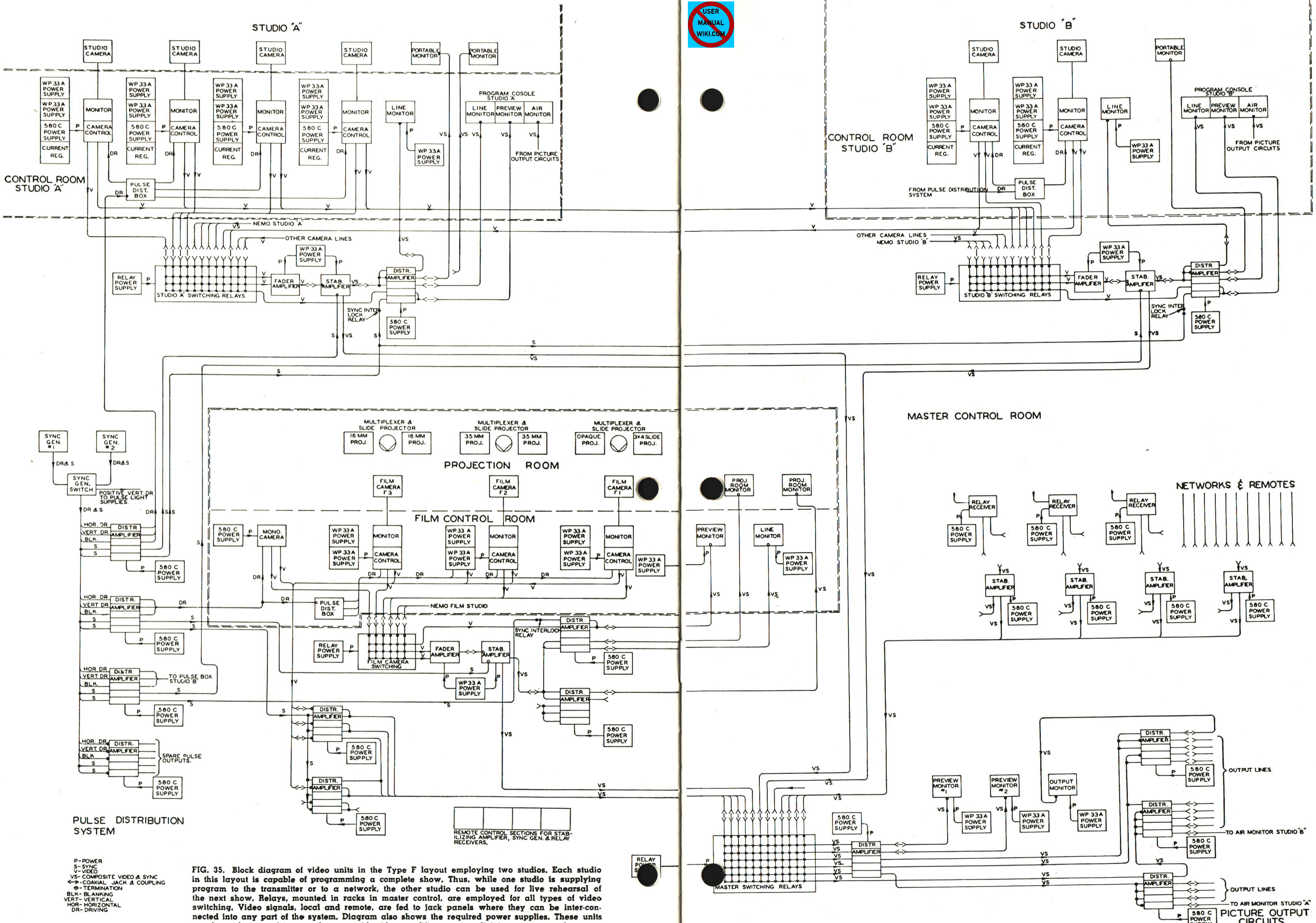


FIG. 35. Block diagram of video units in the Type F layout employing two studios. Each studio in this layout is capable of programming a complete show. Thus, while one studio is supplying program to the transmitter or to a network, the other studio can be used for live rehearsal of the next show. Relays, mounted in racks in master control, are employed for all types of video switching. Video signals, local and remote, are fed to jack panels where they can be inter-connected into any part of the system. Diagram also shows the required power supplies. These units can be rack-mounted in control rooms with video amplifiers, or in adjoining power supply rooms.

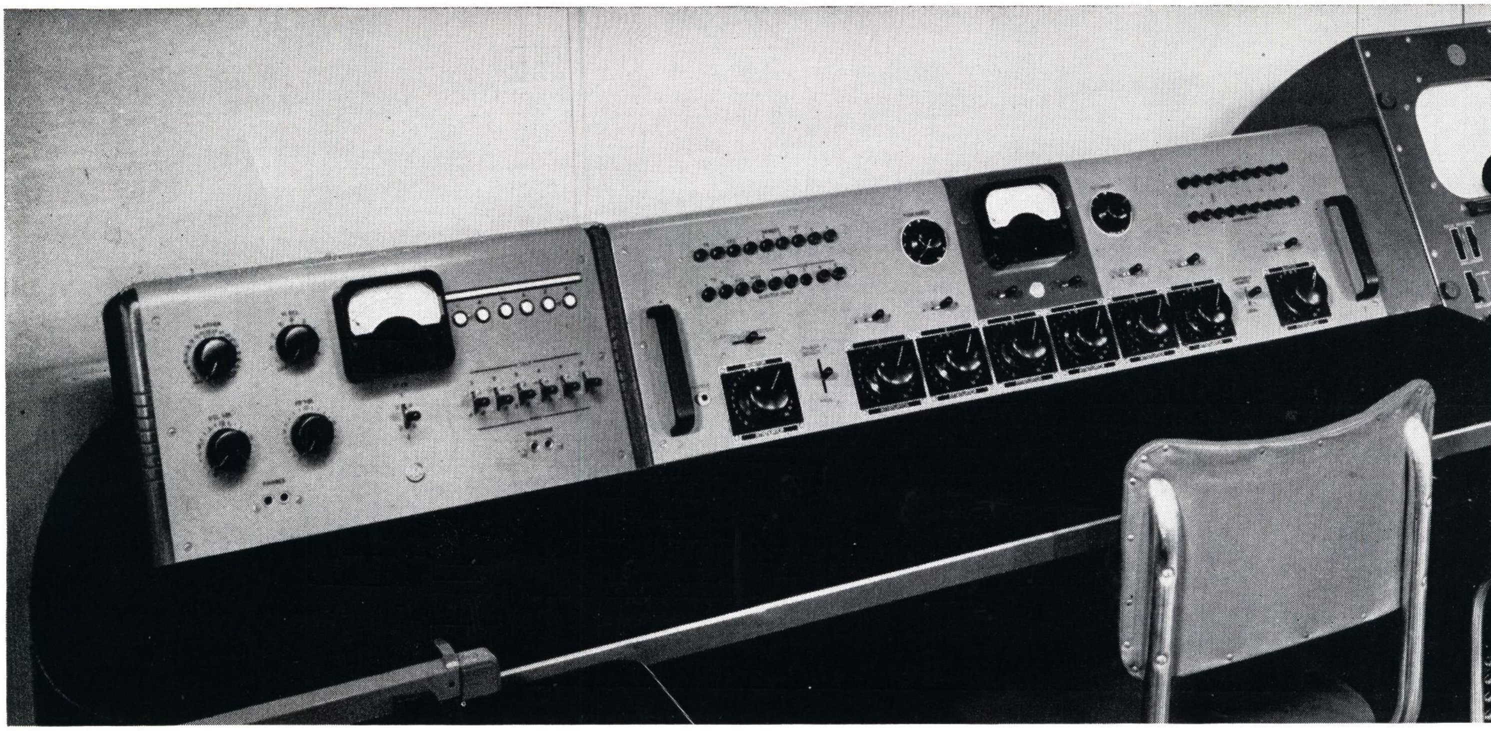
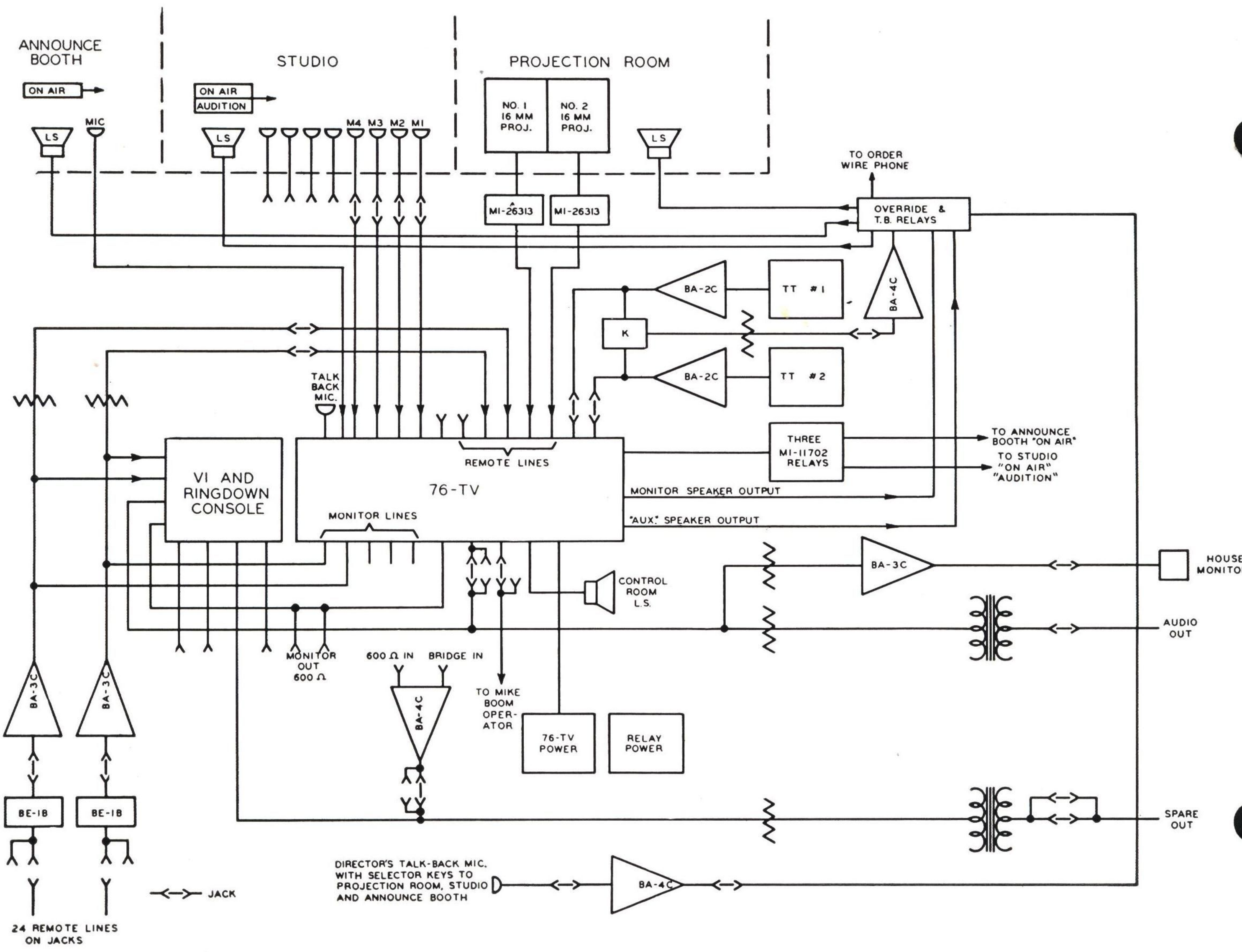


FIG. 36. The audio console above will handle the audio requirements for most television stations. Equipment shown is the Type BCS-3A Auxiliary Switching Unit (smaller unit at left) and the Type 76-TV Consolette. (Below) Block Diagram of the Audio Control Setup for a Television Station Employing a Single Studio, a Projection Room and Control Room.



TELEVISION AUDIO AND COMMUNICATION FACILITIES

The audio facilities at a television studio are similar in most respects to those now in use at AM and FM stations. The principal differences are: (1) provision must be made for handling the sound channel of television film projectors; and (2) means must be provided for feeding transcription sound to loudspeakers in the studios for accompaniment of video performers, or for sound effects.

There are, however, basic differences in talkback and intercommunications requirements, these facilities for video being more elaborate than those used in AM and FM studios. In even the most modestly equipped TV station, the communication system at some time will be called upon to perform these functions: (1) *talkback* (override, carrying cue or orders to studio, projection room, and announce booth—a function of the audio facilities); (2) *Order-Wire* (telephone facilities to offices and to outside lines for communication with remote pickup locations); (3) *Intercom* (two separate channels to provide private and conference wire communications—one channel for production and one channel for technical personnel).

General Considerations

As mentioned at the beginning of this article, the audio engineer is responsible for placement of studio microphones and proper sound pickup. Present practice is to use as few microphones as possible, usually suspended on the ends of movable microphone boom stands. Throughout the show, the microphone boom operator, under the direction of the audio engineer, maintains the correct placement of the boom microphone. He moves it in and out, raising or lowering it as required to secure the best sound pickup. Moreover, the boom operator must keep the boom and microphone out of the view of the camera. Therefore, good communication must be maintained between the audio engineer and the boom operator. Also, the audio engineer should be located so that he has a good view of the outgoing line picture monitor.

Boom stands require the use of lightweight microphones. Moreover, the microphone is subject to considerable movement and, therefore, must be constructed so that it will not pick up wind noise or other noises when the boom is moved about. RCA types 77-D, 44-BX, 88-A, and KB-2C are used for studio pickup. The 77-D, 44-BX and the KB-2C have adjustments to attenuate low frequencies, which is an advantage since it removes some of the boominess present when the microphones are several feet from the source of sound.

Audio for A, B, and C Layouts

A typical TV setup for the types A, B, and C layouts described in this article consists of a single studio, an announce booth, a film projection room and a combined studio, film, and master control room. In addition to the studio and film programs, part of the station's program probably will be from a video network or remote pickups. Basic audio and communications requirements for these three layouts[4] are then as follows:

Studio:

(1) Four studio microphones with four additional microphone lines that can be patched to consolette input circuits.

(2) Studio loudspeaker for turntable feed and talkback.

(3) On-Air Signals.

(4) Intercom and talkback from audio engineer to microphone boom operator.

(5) Intercom and talkback from director to camera operators and video operator.

Film Projection Room:

(1) Control for sound outputs of two film projectors.

(2) Intercom and talkback from director to film projection room.

Control Room:

A. Mixer Facilities

- (1) Mix and switch four microphone lines.
- (2) Patching facilities for four additional microphones.
- (3) Mix audio outputs of two film projectors.
- (4) Mix and switch remote and network lines.
- (5) Mix and switch outputs of two turntables.

B. Intercom and talkback enabling audio operator to talk to microphone boom operators.

C. Intercom and talkback enabling program director to talk to video operator, camera operator and to film projection room.

D. Feed turntables to studio loudspeaker for background purposes, or for accompaniment of vocalist and other similar purposes. (Possibility for the output of the turntable at the same time to be mixed as a part of the consolette program.)

E. Studio equipment to feed loudspeakers in studio control room, studio, announce booth, and projection room. Studio control room equipment able to feed one regular and one spare program line.

F. Program line to feed house monitors through an isolation amplifier.

G. Program cue to camera and boom operators.

H. Termination and equalization facilities provided for 24 remote broadcast and private lines. Ringdown equipment provided for magneto telephones. Equalization of telephone lines to 15 KC.

I. Switching facilities in studio so that program from air monitor and other studios, etc., can be readily monitored.

Announce Booth:

Announce booth containing these audio items:

- (1) a microphone
- (2) a monitor loudspeaker.

The audio control equipment to provide the facilities just outlined consists of the Type 76-TV Consolette, plus a Type B CS-3A Auxiliary Unit and one equipment rack. These audio control facilities are illustrated in the photo and block diagram (Fig. 36).

The BCS-3A contains a VU meter, six ringdown relays and control keys for private line telephone facilities. With the BCS-3A, it is possible to feed turntable outputs to a loudspeaker for vocalist accompaniment, or for background purposes. The equipment rack contains the amplifiers, jacks, equalizers and power supplies.

[4] Audio systems for types D, E, and F stations will be described in a forthcoming article devoted to TV audio facilities.

FIELD OFFICES

36 West 49th Street
New York 20, New York

•

1907-11 McKinney Avenue
Dallas 1, Texas

•

502 Citizens & Southern Bank Bldg.
Atlanta 3, Georgia

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221 West 18th Street
Kansas City 8, Missouri

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1355 Market Street
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666 N. Lake Shore Drive
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718 Keith Building
Cleveland 15, Ohio

•

1560 N. Vine Street
Hollywood 28, California

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TELEVISION BROADCAST EQUIPMENT

RADIO CORPORATION of AMERICA

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TELEVISION TECHNICAL TRAINING PROGRAM

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SECTION II

TELEVISION FIELD PICKUP EQUIPMENT

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TELEVISION FIELD PICKUP EQUIPMENT

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TELEVISION TECHNICAL TRAINING PROGRAM

TELEVISION FIELD PICKUP EQUIPMENT *

INTRODUCTION

In every art, advances occur at intervals which serve as distinct milestones in the progress of that art. They are steps which overcome major limitations, and thus open up new fields which men have only dreamed about before. Such an advance has recently occurred in the art of television in the development of the image-orthicon pickup tube.

Television has made much progress in the past two decades in such things as higher definition, greater picture brilliance and size, greater immunity to interference in transmission, improved techniques in propagation, and the introduction of color on a laboratory scale. However, the requirement for intense illumination of the televised scene has dogged the industry from its inception up to the very recent past. This requirement has limited outdoor pickups to daylight hours with bright sunlight, and indoor pickups either to motion-picture film or to studios where enormous amounts of lighting on the order of 1000 to 1500 foot-candles could be provided.

The lighting equipment for such studios not only represents a large capital investment, but it entails excessive operating expense. Costly air-conditioning systems only partially alleviate the discomfort of performers, who literally have to "sweat it out" in scenes that cannot be retaken if things do not go right the first time. From the producer's point of view, such intense lighting produces flat, shadowless, uninteresting effects which greatly limit the artistic possibilities of the medium.

These conditions are always attendant on operation with the iconoscope as a pickup tube. The iconoscope itself is one of television's milestones because it introduced the storage principle to the art, made the system all-electronic, and thus brought television into a form which has commercial possibilities. It represented a big stride in sensitivity over previous nonstorage devices. However, its lack of sufficient sensitivity to operate satisfactorily outdoors in cloudy weather or in late-afternoon dusk, or indoors under moderate lighting, has been, and still is, its principal limitation.

The next step in the direction of greater sensitivity was the introduction in 1939 of low-velocity scanning in the RCA-1840 orthicon-type of pickup tube. It retained the storage principle and added a great improvement in efficiency with a corresponding improvement in sensitivity of the order of five times. This meant the possibility of reducing incident illumination to about 200 or 300 foot-candles.

Wartime development of military television equipment[1] accelerated work on a pickup tube which had its beginnings before the war started. The result of this work we know today as the image orthicon, a pickup tube which embodies the old principles of storage and low-velocity scanning, and, in addition, the principles of image-electron multiplication and signal-electron multiplication. The tube and the theories underlying its operation and incorporation into television cameras have been described in detail in recent literature.[2]

The image orthicon has as its most outstanding characteristic very great sensitivity, of the order of 100 times greater than that of the iconoscope. One of the most obvious and useful results of the high sensitivity of the tube is that, under medium or high illumination, the lens opening may be stopped down to a very small size, thus giving an enormous depth of focus. Even under relatively low illumination, the depth of focus of the image orthicon is much

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* *Reprinted by permission of Institute of Radio Engineers from an article entitled* "NEW TELEVISION FIELD PICKUP EQUIPMENT EMPLOYING THE IMAGE ORTHICON" *by John H. Roe, Radio Corporation of America, RCA Victor Division, Camden, N. J., published in I.R.E. Proc., Vol. 35, No. 12, December 1947, pp. 1532-1546.*

1 *A series of papers on military television developments appeared in RCA Rev., Vol. 7, September and December, 1946.*

2 *A. Rose, P. K. Weimer, and H. B. Law,* "THE IMAGE ORTHICON - A SENSITIVE TELEVISION PICKUP TUBE," *Proc. I.R.E., Vol. 34, pp. 424-432; July, 1936.*

greater than that obtainable with less-sensitive tubes.

In contrast with the simple orthicon, the image orthicon has another outstanding characteristic; namely, its ability to accommodate a tremendous light range without serious loss of contrast. The scene illumination may be changed from dark shadows to bright sunlight and back again without losing essential picture information.

Other important characteristics are: (a) small target size, (b) small over-all tube size, and (c) high output signal level.

The small target area makes it possible to use relatively small lenses which lend themselves to a reasonable turret design. Lenses for such a field are readily available in a variety of focal lengths and apertures. The small size of the image orthicon is a factor of great importance in making the camera itself as compact and light as possible.

All previous types of standard pickup tubes have such low signal outputs that very high-gain amplifiers are required where shot noise in the first stage limits the signal-to-noise ratio. The image orthicon, in contrast to these, produces a high signal output, so that a comparatively low-gain amplifier may be used. Hence, shot noise in the amplifier is very low, compared with noise in the beam.

These characteristics have opened up a wide field of opportunities in television programming, such as night games under standard incandescent lighting, daytime athletic and other events lasting into late-afternoon shadows, and all sorts of special events at any time of day or night, as well as studio and theatrical shows with standard stage lighting, and a host of industrial and military applications.

FIELD PICKUP EQUIPMENT

The first and most obvious application for the image orthicon is in field or remote-pickup equipment.[3] This type of equipment must be so designed that it can be transported quickly and easily and set up almost anywhere for operation with little more than a moment's notice. Usually, under such conditions, it is impossible to control the amount of illumination on the scene; hence, if it is to be truly useful, the pickup device must have sufficient sensitivity and range to function with the amount of light available at any time or place. The new field pickup equipment being produced by the Radio Corporation of America has been designed to meet this need.

In the design, consideration has been given to the possible needs for using the field equipment under three different types of conditions: These are:

1. In temporary locations, inaccessible to vehicles, to which the equipment must be carried by hand.

2. In temporary locations accessible to vehicles where all of the equipment except the cameras may remain in a suitable mobile unit which serves as a control center.

3. In permanent locations where the equipment may be used for studio productions.

One of the first two of these conditions is encountered in every operation in the field. The third condition may exist in the case of a small broadcaster who wishes to begin studio operations with a minimum of capital investment. He may wish to use the same equipment for both field and studio work in case he is operating on a limited schedule which permits the necessary breaks for transporting the equipment. This third condition may also apply to the ambitious broadcaster who, like many in these times, is unable to obtain any other type of equipment immediately, and who, in spite of this, wishes to get the training of technical and program personnel under way for more extensive operations in the future.

These conditions, together with electrical considerations, dictate in large measure how the equipment should be divided into units. Each unit should be small and light enough to be carried by one man. On the other hand, the number of units must be kept to a reasonable minimum in order to facilitate assembling and disassembling in the field. The shape of the units must permit easy handling, and also permit setting them side by side on a bench or table so that the assembly of units has the general appearance and utility of a console. Simple and rapid means of electrical interconnection are a further requirement. To meet these requirements, most of the major units of the field equipment have been housed in cases resembling a medium-sized suitcase in both shape and dimensions. Cameras, view finders, and master monitors have special requirements which necessitate deviations from this standard shape.

The block diagram of Figure 2-1 shows the arrangement of major units required to make up a system of field pickup equipment consisting of two or more cameras, with necessary switching facilities, radio relaying, and a mobile unit. It includes also a simplified schematic diagram of the interconnections. The two large upper-left-hand blocks show the actual camera equip-

[3] *R. E. Shelby and H. P. See,* "FIELD TELEVISION," *RCA Rev., Vol. 7, pp. 77-93; March, 1946.*

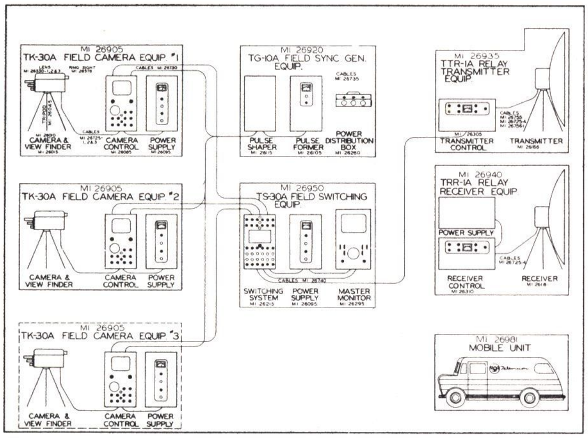

Figure 2-1 - Block Diagram of Field Pickup Equipment

The system illustrated provides a maximum of flexibility with a minimum number of separate units. As a system it provides many features which make for ease in operation and fine performance.

Figure 2-2 illustrates the equipment required for a two-camera setup, mounted on a desk such as may be used for studio operation. The units

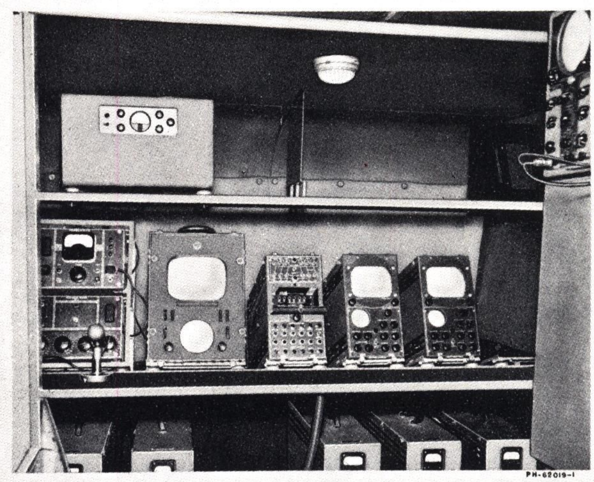

Figure 2-3 - Installation of Field Equipment in the Mobile Unit

ment required for a standard two-camera system. The third block below (in dotted lines) illustrates how additional cameras, up to a total of four, may be included in the system. The blocks (in solid lines) in the center and right-hand side of the diagram show equipment which is common to the entire system, whether it be composed of two, three, or four cameras, and which need not be duplicated when cameras are added to the system. The dotted block in the lower center of the diagram shows additional monitoring equipment which may be added to provide a second viewing position for an announcer, for visitors, or for other special purposes. In the case of single-camera operation, the switching equipment and auxiliary monitoring equipment are omitted.

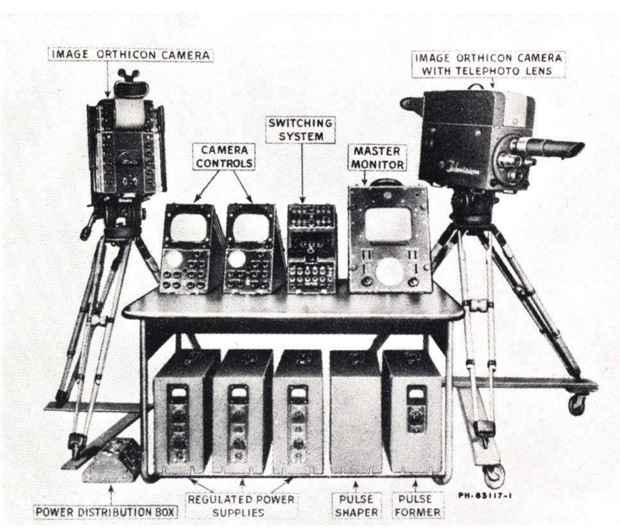

Figure 2-2 - Two-camera System Including Desk

on top of the desk include two camera controls, a master monitor, and a switching system. These units contain all the controls normally required by the operators during the program. The other units under the desk are those which normally require little or no attention during program time. These units are the synchronizing generator and the power supplies.

Figure 2-4 - Mobile Unit in Operation, with Camera and Relay Transmitter on the Roof

Figure 2-3 shows the same equipment mounted in a similar manner in a mobile unit. Figure 2-4 is an external view of the mobile unit, showing how access to the roof is provided through a hatch, and how a camera may be set up for opera-

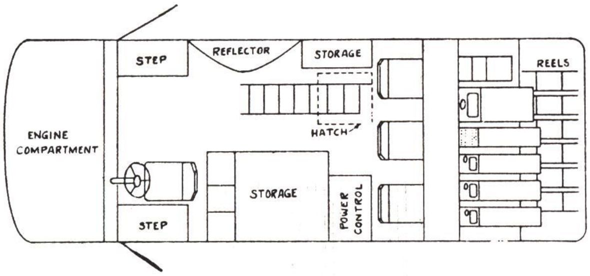

Figure 2-5 - Plan Diagram of the Mobile Unit

tion on the roof. Sufficient space is also available on the roof for setting up a microwave relay transmitter. Storage space for a maximum of 1200 feet of camera cable is provided on reels with swing-out brackets at the rear of the mobile unit. The general plan of the mobile unit showing operating positions and storage space for cameras, tripods, view finders, relay transmitter, sound-pickup equipment, and miscellaneous accessories, is illustrated in Figure 2-5.

CAMERA

Full advantage has been taken of the relatively small size of the image-orthicon tube in designing a compact camera. The dimensions of the case, including the cover, but without lenses or view finder, are 20 x 10-1/2 x 11-1/4 inches, and the weight is 65 pounds (see Figures 2-2 and 2-9).

The principal features of the camera are as follows:

1. Image-orthicon pickup tube.
2. Completely self-contained deflection circuits.
3. A four-position lens turret with rear control for quick change of lenses.
4. Miniature tubes in picture preamplifier.
5. Small, flexible camera cable.
6. Operation over a long cable (up to 1000 feet).
7. Forced-air ventilation.
8. Accessibility for servicing.
9. Rugged mechanical construction.

Though the use of lens turrets is well known on photographic cameras, their application to television cameras has not been attempted before, mainly because the lenses required for iconoscope and orthicon cameras are too large and heavy for a suitable turret mechanism. Furthermore, the use of optical view finders on many such cameras, requiring matched pairs of lenses at least doubles the difficulties of turret design.

The useful photocathode area of the image orthicon is a rectangle 0.96 inch in height by 1.23 inches in width. Since this is approximately the same size as the frame of many miniature photographic cameras which use 35-mm. film, it is possible to use lenses designed for such cameras. The Kodak Ektar lenses for the Ektra camera provide a useful series of focal lengths which have been applied to the image-orthicon camera. Available lenses include 50-, 90-, and 135-mm. focal lengths. These lenses are light in weight and are excellent for turret operation. Special lightweight lenses up to 25 inches in focal length and with *f*/5 apertures have been constructed using achromats in black bakelite barrels with quick-change slotted mountings. These weigh only 2 to 3 pounds and may be attached to the turret (see Figure 2-2).

The four-position turret is mounted on a hollow shaft which extends through the camera to a control handle and indexing mechanism in the rear at the operator's position. Releasing the indexing detent automatically cuts off the picture signal while the turret is being rotated to another position.

Optical focusing is accomplished in a novel manner by moving the pickup tube, along with its focus and deflection-coil assembly, instead of by motion of the lens. The mechanism is self-locking in any position of the camera. The greatest advantage in this system is the obvious simplification of the turret. A second important advantage is the increased range of focus obtainable when lenses with individual focusing mounts (such as the Ektar lenses) are used. The total available relative motion between lens and target is then the sum of the individual motions. A further advantage of the individual focusing mounts is that lenses of different focal lengths may be preset to focus on the same scene, thus eliminating the need for adjusting optical focus after rotation of the turret.

Figure 2-6 shows a top view of the camera in which the coil assembly and magnetic shield are exposed. The coil assembly is supported on a steel plate which moves on three rollers. At the rear of the compartment may be seen the focusing drive screw and the wiring to the base of the image orthicon. A small trap door at the rear end of the magnetic shield box exposes the cross field or alignment coil and the gear drive used for rotating this coil.

Figure 2-7 shows the focus coil alone. This is a simple, random-wound solenoid long enough to enclose both the deflecting coils and the image section of the image orthicon tube with an overhang of about one-half inch at the front and one inch at the rear. The deflecting coil assembly, which is mounted within the focusing coil, is illustrated in Figure 2-8.

The deflection circuits are included in the camera in order to reduce the number of major units in the field equipment. To make the camera capable of operating over a long cable, it is necessary to locate the deflection generators either in the camera itself or in an auxiliary unit adjacent to the camera. Locating the deflection circuits and part of the picture preamplifier in an auxiliary unit makes it possible to keep the size and weight of the camera to a minimum. Such an arrangement, however, complicates the system by increasing the number of units, and hence the number of connecting cables and the time and effort required for setting up, dismantling, and transporting the equipment. A further objection is that, in some field operations, an auxiliary unit is a serious nuisance, especially when the camera has to be set up on a small stage or platform where space is restricted. In the case of the image-orthicon camera, it is possible to include all of these circuits in the one unit without making the camera unreasonably large or

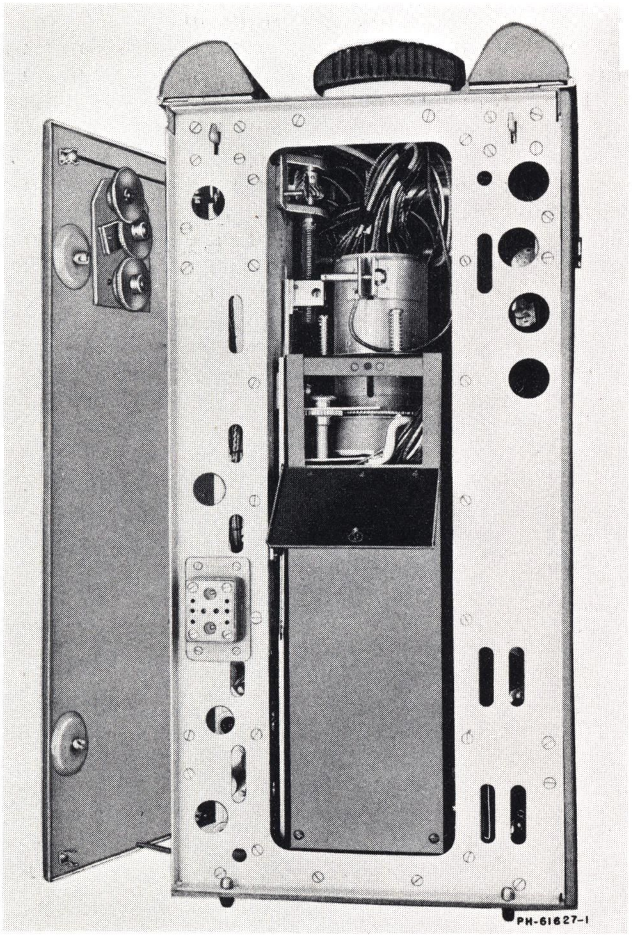

Figure 2-6 - Top View of Camera, Showing Coil Assembly

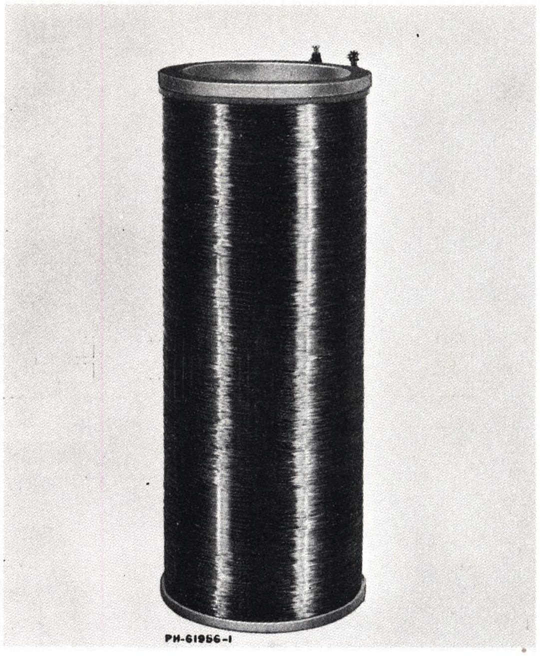

Figure 2-7 - Focus Field Coil for the Image Orthicon

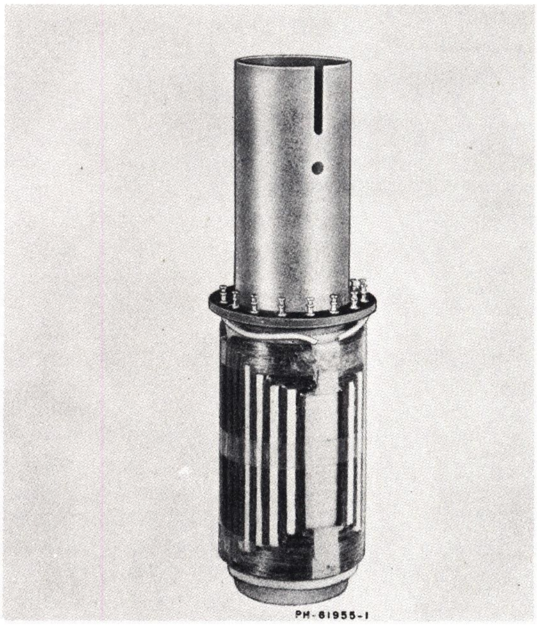

Figure 2-8 - Deflecting-coil Assembly for the Image Orthicon (Outer Tube Removed) heavy. With this arrangement, it is necessary to transmit over the cable only the timing information in the form of driving pulses. The transmission lines used for this purpose are easily terminated with resistors, and the pulses, which are not unduly critical as to wave form, are then easily amplified to usable levels.

The horizontal-deflection circuit, in common with similar circuits in other parts of the system, employs two new types of tubes, the 6BG6G and 6AS7G. The 6BG6G is similar to the 807, but has special characteristics for deflection output service. The 6AS7G is a twin triode, having very low plate resistance and large power capabilities. It is used as a damper or reversed-current output tube.

The horizontal retrace period is made about 10 per cent of the total horizontal scanning period, in order to avoid the necessity for artificial compensation for delay in long camera cables. The difference between the minimum kinescope blanking width (16 per cent) and this retrace is 6 per cent, or 3.8 microseconds. This is just slightly in excess of the time required for a round trip (2000 feet) in a 1000-foot cable.

The high voltage required for operating the image-orthicon tube totals about 2000 volts, - 500 volts required in the image section and + 1500 volts in the signal multiplier. This is generated by amplifying and rectifying the pulse signal that appears across the horizontal deflecting coils. Negative pulses are partially integrated and fed to the grid of a 6V6GT amplifier with its plate coupled to the primary of a special step-up transformer. The screen and cathode circuits of this amplifier are made degenerative in such a way as to compound the plate current. As a result, the peak plate current at the beginning of each retrace period is constant over a two-to-one range of pulse input to the grid. Thus the voltage fed to the rectifier is nearly independent of the horizontal scanning amplitude (width). The high-voltage transformer includes a small heater winding for the filament of a type 1B3/8016 rectifier. Suitable voltages for the various electrodes in the image orthicon are obtained from a filtered bleeder.

Negative feedback is employed in the vertical-deflection circuit by deriving a voltage from the drop across a small resistor in series with the deflecting coils and, after amplification, injecting the feedback signal into the plate circuit of the first sawtooth-amplifier stage. This feedback does two important things. It eliminates almost entirely the effect of iron saturation in the transformer core and nonlinearities in the amplifiers. It also minimizes the effect of varying tube characteristics, and makes the vertical scanning linearity largely independent of amplitude.

Blanking signal for the target in the image orthicon is derived from the horizontal and vertical driving signals by mixing.

Controls associated with the scanning circuits are all located in the camera. These include height, width, centering, and linearity controls. Other controls also located in the camera are preamplifier gain, image accelerator, orthicon decelerator, and horizontal shading. None of these controls requires attention during actual operation, and hence the camera man is left free to aim the camera and focus the optical system.

The picture signal is amplified in a five-stage preamplifier built into the camera. The preamplifier employs miniature tubes and circuits compensated to give uniform output up to approximately 8 mc. The cathode follower in the final stage serves to feed the signal over a coaxial transmission line to the camera control, and also to provide signal for operation of an electronic view finder which may be used with the camera.

Components in all parts of the camera are accessible for servicing, and can be removed easily in case replacement becomes necessary.

A single camera cable contains all the electrical connections to the camera. It includes three 50-ohm coaxial transmission lines and 21 other conductors used for power, control, and communication. The cable is unusually small in diameter (0.84 inch) and light in weight.

VIEW FINDER - Television cameras have been equipped in the past with a wide variety of view finders, ranging from two screw heads used as rifle sights, through wire frames and double-lens systems, to electronic finders in which the scene is reproduced on small kinescopes mounted beside or above the cameras. Each type has advantages, but no one type has all the desired characteristics. In the cases of iconoscope and orthicon cameras, the optical view finder employing a second lens identical with the camera lens has enjoyed the greatest popularity because it not only serves to indicate focus, but is capable of including portions of the scene outside of those actually being televised. This has been considered important because the camera man can see and avoid unwanted objects before they intrude themselves in the picture.

In the case of the image-orthicon camera, the double-lens type of optical finder becomes completely useless when the equipment is used under limiting low-light conditions. This is true because the image orthicon can operate with such low illumination that the image on a ground-glass screen is nearly invisible. Thus the electronic view finder is the only remaining type capable of indicating both focus and the outline of the scene. It has two distinct advantages over the optical system. It is entirely free of parallax errors, and it provides an erect image where a single-lens direct optical finder provides an inverted image. The electronic view finder has a disadvantage in that it cannot include anything outside of the televised scene.

The view finder designed to be used with the image-orthicon camera employs a flat-faced 5-inch kinescope tube (type 5FP4) with about 7000 volts on the second anode. This arrangement provides a picture with sufficient brilliance to be seen readily under bright ambient light. The view finder is constructed as a separate unit to be mounted on the top of the camera. The two units are styled to appear as a single unit when thus assembled.

The physical arrangement is such that the kinescope faces the operator at the rear of the camera. The face of the tube may be shaded with either of two types of viewing hoods. One of these includes two mirrors in a periscopic arrangement which may be reversed so that the operator's eye level is either above or below the kinescope, depending on the height of the camera. The other hood provides a direct view of the kinescope. A single cover opens on a hinge at the front, exposing the entire internal assembly (see Figure 2-9).

The circuits include the picture and blanking amplifiers required to drive the kinescope, and also the deflection generators and high-voltage supply. The latter is a pulse type of supply associated with the horizontal-deflection circuit. Necessary controls are accessible at the rear in line with the operating controls on the camera. All electrical connections are made through a multicontact plug and receptacle (see Figure 2-6).

An auxiliary view finder in the form of a polaroid ring sight may be mounted on top of the periscope viewing hood (Figure 2-2), or, in the absence of the electronic view finder, on the camera itself. This ring sight produces a series of concentric spectral interference rings which appear to be at a considerable distance in front of the sight. Because they appear at a distance, the eye can observe the rings and the scene simultaneously with a minimum of strain. This device is useful in following action which moves too rapidly and too far to be followed readily on the kinescope. Its usefulness is limited, however, because it does not indicate either correct focus adjustment or the boundaries of the scene. It is simply an aiming device.

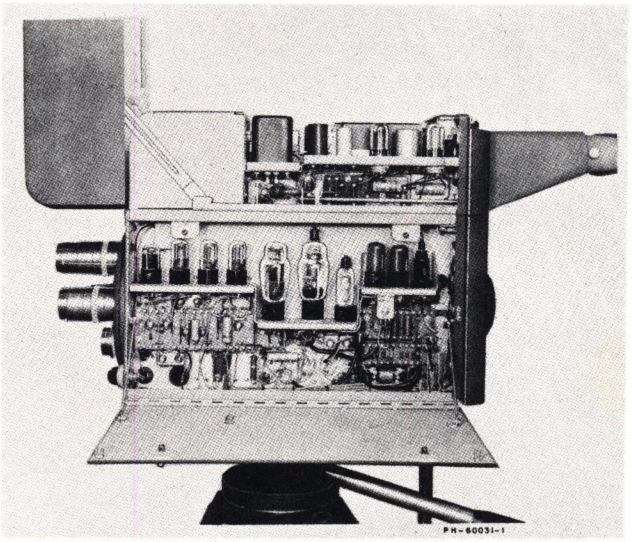

Figure 2-9 - Deflection-amplifier Side of the Camera and View Finder (Internal View)

CAMERA CONTROL

The camera control (Figure 2-10) is a unit which performs all of the functions not already performed in the camera itself that are necessary to the production of a complete composite picture signal. These functions include:

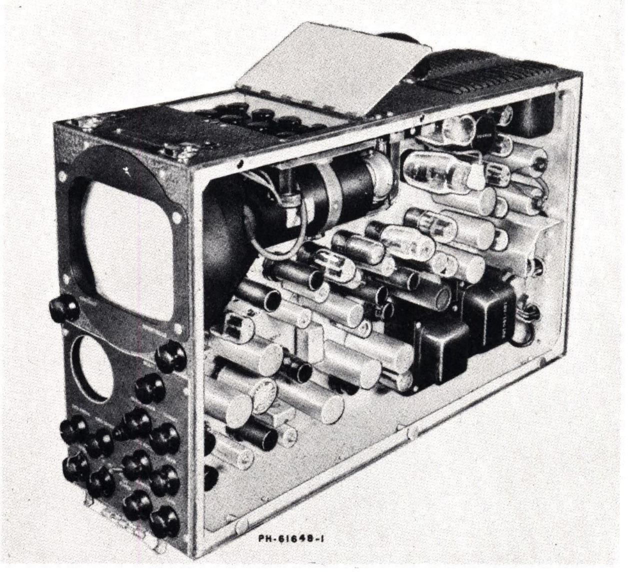

Figure 2-10 - Field-camera Control

1. Amplification of the picture signal to the standard level required for feeding outgoing lines.

2. Addition of kinescope blanking signal.

3. Establishment and maintenance of the peaks of the blanking pulses at true "black" level.

4. Addition of the receiver synchronizing (sync.) signal in cases where only a single camera is in use.

5. Monitoring of the finished picture signal to check the accuracy of optical and electrical focus in the camera and the general quality of performance of the camera chain by means of the following:

   (a) A picture monitor tube (kinescope) which reproduces the scene being televised.

   (b) A wave form monitor tube (cathode-ray oscilloscope) which shows the wave form of the picture signal and measures the amplitude of this signal.

6. Controlling electrical focus and other parameters involved in operation of the image-orthicon tube in the camera.

From consideration of these six functions it is apparent that the camera control is necessarily a complex unit, for it includes all the circuits and components found in that part of a television receiver which follows the second detector, also those required for a wide-band cathode-ray oscilloscope, and, in addition, amplifiers, special circuits and controls, and cable connectors required directly for operation of the camera.

As indicated previously, the shape of the camera control is that of a medium-size suitcase, the dimensions being approximately 8x15x24 inches (Figures 2-2, 2-10, and 2-11), and the weight about 65 pounds. The chassis and case are spot-welded into a rigid, durable assembly. The kinescope (type 7CP4), the C.R.O. tube (type 3KP1), and the most important controls are mounted on the front end of the case. All small tubes, capacitors, and transformers are mounted on one side of the chassis, with wiring on the opposite side. Controls of secondary importance are mounted under a trap door in the top of the case. Past experience and a good deal of thought have produced a chassis layout which provides a maximum of accessibility for servicing, and at the same time a system for rigid, vibration-proof mounting of components which contributes much to trouble-free

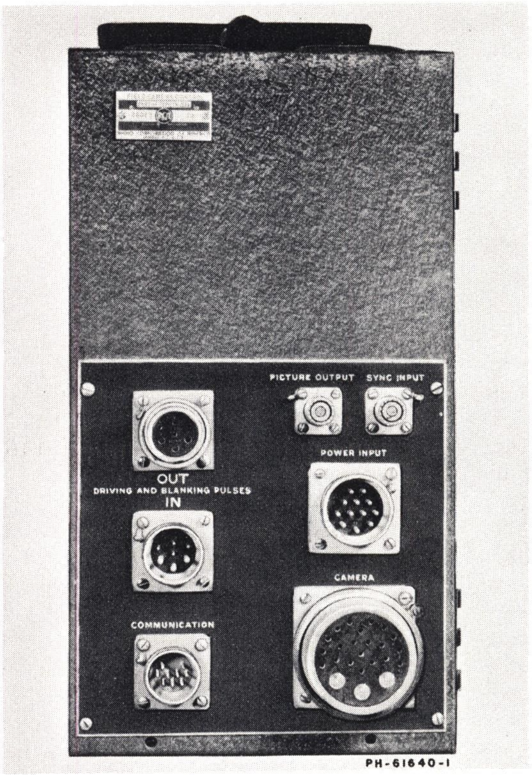

Figure 2-11 - Rear of the Camera Control

operation. A removable metal cover protects the cathode-ray tubes and controls during transportation. The two side panels or covers are easily removed by releasing three cowl fasteners at the top of each, and listing them from three spring retainers at the bottom. All external electrical connections are made through plugs and receptacles on the rear of the case (Figure 2-11). This same general construction is followed in the other suitcase units described hereinafter.

The circuits in the camera control include:

1. The picture amplifier, with stages for mixing kinescope blanking and synchronizing pulses.
2. A picture amplifier for the monitor kinescope.
3. A picture amplifier for the C.R.O. tube (for vertical deflection).
4. Deflection circuits for both C.R.O. tubes.
5. Distribution amplifiers for feeding driving pulses to the camera.
6. A filament transformer.
7. A high-voltage transformer, rectifier, and filter for the C.R.O. tubes.
8. Camera circuit controls.
9. "On-the-air" tally and intercommunication system.
10. Remote power control.

The picture amplifier consists of several stages of types 6AC7 and 6AG7 tubes in conventional frequency-compensated circuits. One stage in this amplifier performs the very important function of establishing the peaks of blanking at "black level." To do this, the control grid is clamped at the end of each scanning line to an arbitrary reference potential. Because the target in the image orthicon is blanked during the scanning retrace (*i.e.*, made sufficiently negative to repel the scanning beam) the picture signal from the camera during this retrace period is fixed with respect to black level, though it may vary continuously with respect to an arbitrary fixed reference because of the addition of hum, power-supply surges, or other spurious signals. The clamping action serves to set up a fixed relationship between the actual black level in the retrace periods of the picture signal and the arbitrary reference by connecting the control grid mentioned above to the reference potential through a very low impedance. At all times, except during the retrace periods, the grid is disconnected from the reference, and thus is free to follow the normal potential variations in the picture signal.

An important by-product of this clamping action is the elimination of the low-frequency components of any spurious signals, provided they do not have sufficient magnitude to cause amplitude modulation in any preceding stage. Hence, the clamp circuit removes power-supply surges and low-frequency hum, and minimizes microphonics. In fact, it limits the amplitude of any spurious additive signal to the amount which occurs in the period of one scanning line. (For a more detailed description of clamping, see the Appendix.)

Kinescope blanking is mixed with the camera signal just ahead of the clamper. It provides undistorted, noise-free blanking intervals by the addition of independent, carefully controlled pulses. Since this added blanking is constant in amplitude, it does not affect the clamping action in any way except to shift the constant relationship between black level and the reference to a different constant value. After clamping, the combined camera and blanking signal is clipped near black level thus producing a final signal in which the peaks of blanking bear a definite relationship to black level. The clipper makes use of a diode as a switch in series with the picture signal circuit. It depends for its accuracy in maintaining black level on the clamping which precedes it. This clipper is somewhat more complicated than the usual plate-current-cutoff type of clipper, but is justified because it cuts off very abruptly and is almost perfectly linear in the neighborhood of cutoff. (See Appendix.) A manual control (BLANKING) adjusts the clipping level to any desired point near black level, and thereafter the circuit maintains clipping at that level. Usually the clipper is adjusted so that the peaks of the blanking pulses are slightly "blacker than black," thus assuring complete removal of the retrace lines in receiver kinescopes.

D-C restoring circuits maintain black level (or sync. peaks when sync. is present in the output) on the grid of the kinescope and on the grids of several stages where it is important to minimize distortion.

Deflection circuits for the kinescope are of the driven type. These circuits are of the same general kind as those used in the camera described previously, the only differences being in the deflecting-coil design and matching transformers.

Seven electrical controls, grouped on the front panel, provide for maintenance of proper operating conditions in the camera and associated picture-amplifier circuits in the camera control during the program. These are: (1) GAIN, (2) BLANKING, (3) BEAM CURRENT (ORTH.), (4) ORTHICON FOCUS, (5) IMAGE FOCUS, (6) TARGET POTENTIAL, and (7) MULTIPLIER FOCUS.

Only the first two of these required frequent checking during operation. However, the others are easily available to the operator at the camera control without the need of distracting the attention of the camera man, who is occupied with his normal duties. Location of these controls in the camera control is particularly useful in the process of making adjustments when a new image orthicon tube is installed in the camera, because the number of adjustments to be made in the camera itself is reduced to a minimum. Controls of secondary importance, such as size and centering for the kinescope and C.R.O., are located under a small trap door on top and near the front of the unit, easily accessible to the operator.

Plate current for all of the amplifier tubes is obtained from a regulated power supply entirely separate from the camera control. A power switch on the front panel of the camera control actuates a relay in the power supply which, in turn, opens or closes the power-input circuit for the entire camera chain.

POWER SUPPLY

The problem of providing the large amount of highly stabilized d.c. required for the large number of amplifier tubes in a camera chain has been solved in a unique way in the field power supply. The problem resolves itself into one of finding means to reduce the weight of the unit to a point where one person can carry it. The difficulty may be understood when it is pointed out that the total plate-current drain in a single camera chain is approximately 1 ampere at 235 volts, regulated within limits of less than ± 0.5 volt. The regulation does not constitute the major part of the problem, but simply adds to it by increasing the total voltage required from the rectifier.

The general attack on this problem was developed several years ago in the design of portable television equipment for the type-1840 orthicon.[4] A very light-weight transformer with the core divided into sections, with large openings in the end turns of the windings and with only a small fraction of the usual amount of iron and copper, was designed to be used with a continuous blast of air through the openings (Figure 2-12(a)). This transformer, together with the blower and motor, weighed less than 20 pounds, and the entire power supply, including case, transformer, blower, tubes, and other components, weighed only 53 pounds. This design

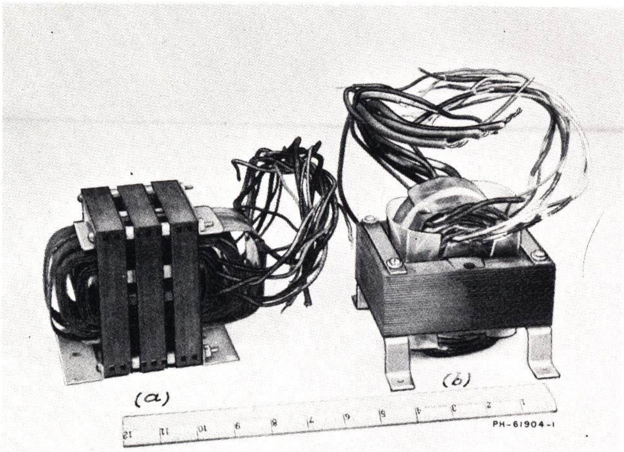

Figure 2-12 - (a) Prewar Design of a Forced-air-cooled Power Transformer. (b) New Design.

achieved the required objective, and gave reasonably good service in field use for several years.

In the field power supply for the image-orthicon equipment, a new and much improved transformer has been developed by making use of silicone enamel on the wire and glass fabric impregnated with silicone varnish for insulation between layers of the windings. The core is not sectionalized, and the windings are tight, as in conventional transformers (Figure 2-12 (b)). The running temperature may be as high as 180°C. without danger of deterioration. As a result of this design, the overall weight of the field power supply has been kept the same as in the earlier model, and the reliability has been increased.

New regulator tubes have made possible an improvement in efficiency. The type 6AS7G, a heavy-duty twin triode with extremely low plate resistance and the ability to dissipate 25 watts, is used for series regulation. This is

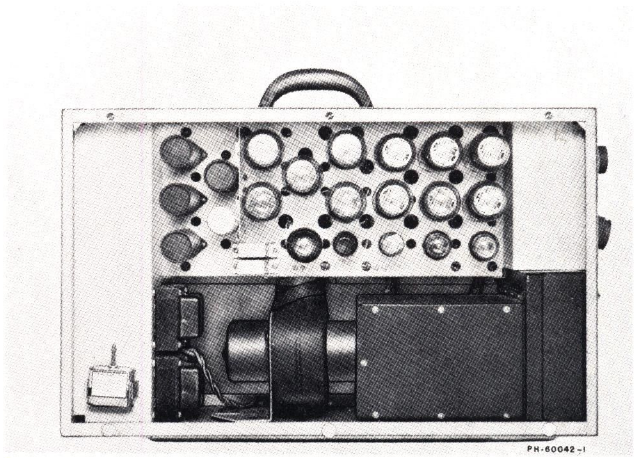

Figure 2-13 - Field Power Supply, Tube Side

the same tube that is used as a damper in the horizontal-deflection circuits. These tubes have appreciably less voltage drop than other types previously used in such service, and hence are more efficient. They also have very high transconductance, and therefore provide improved regulation control.

The rectifier is connected to a two-stage choke-input filter using electrolytic capacitors, through a thermal time-delay relay which prevents application of the high d-c voltage until all tube heaters have attained operating temperature.

A 6SL7GT tube functions as a two-stage control amplifier, and two OD3/VR150 tubes serve as voltage references.

The field power supply is capable of delivering 950 ma. at 285 volts continuously to the

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[4] *M.A. Trainer,* "ORTHICON PORTABLE TELEVISION EQUIPMENT," *Proc. I.R.E., Vol. 30, pp. 15-19; January, 1942.*

main load, and, in addition, 75 ma. to the focusing field coil in the camera. This latter supply is current-stabilized so that changes in the resistance of the coil do not change the current. Figure 2-13 is a side view of the field power supply, showing the transformer housing, blower and tubes.

The primary power circuit includes means for switching and metering of taps, so that a wide range of supply voltage may be accommodated. Provision is also made for metering currents and voltages in parts of the output system.

SYNCHRONIZING GENERATOR

The new field synchronizing generator, which is part of the image-orthicon equipment, is designed on the same basic principles as earlier models, but improvements and new features have been added which make its performance the equal in every respect of that of the studio type of generator. Equality of performance is obviously necessary, especially in view of the increasing importance of field operations in television programming.

The field synchronizing generator comprises two suitcase units having the same size and shape as the field camera control. They are called the field pulse former and field pulse shaper, respectively. These two units generate four distinct signals required for operation of the entire television system, including the receivers. All four signals, though different in wave shape, are accurately synchronized with each other by being derived from a single primary frequency source. Two of these signals appear directly in the composite picture signal which modulates the r-f carrier. They are "kinescope blanking" and "synchronizing" (or "sync."), respectively. The wave shapes of these two signals are specified completely in standards recommended by the Radio Manufacturers Association.[5] The remaining two signals, "horizontal driving" and "vertical driving," respectively, are simple pulse signals used locally in the pickup equipment for triggering camera and monitor scanning circuits, and for target blanking and clamp-circuit keying.

The principles underlying the operation of this generator have been described fully in a previous publication.[6] No basic changes have been made in the arrangement of circuits, but refinements have been included to increase the stability of the primary frequency source and also to improve the steepness of wave fronts in the outputs. Among these, specifically, are a crystal oscillator which may be used in locations where the power supply frequency is unstable, an improved a-f-c circuit for lock-in with a 60-cycle power supply, an additional counter to reduce the maximum number of steps in any given counter, and a cathode-ray-tube indicator to provide a means of quickly checking the operation of the counters.

One of the two units includes a built-in regulated power supply, thus making the synchronizing generator completely self-contained in the two units. Separation of the circuits occurs at a point where only three signals require connections between units. A single multiconductor cable connects the pulse former to the pulse shaper. The only input to the pulse former is a-c power. Output from the pulse shaper is split in two cables, one a single coaxial line for synchronizing signals and the other a multiple coaxial cable for the other three signals. The two suitcases appearing in the lower right hand corner of Figure 2-2 are the pulse shaper and pulse former.

SWITCHING SYSTEM

One of the most important operations in television programming is that of switching from one camera to another. Switching must be accomplished smoothly without either interrupting or disturbing the receiver synchronizing, even momentarily. If precautions are not taken to avoid surges in switching, it is possible that the sync. may be clipped later in the system during the period of the surge. Some receivers are very sensitive to such interruptions. Cases have been known in the past where switching surges have been so large as to overload the transmitter and throw it off the air. It is not possible to experience such difficulties in properly designed television systems today because means are used to maintain constant black level at all points where surges are harmful. Since switching is likely to produce surges, it is desirable to eliminate them at this point. A successful means for accomplishing this is the clamp circuit which was described previously in the section on the camera control. This cir-

[5] "SYNCHRONIZING GENERATOR WAVEFORMS," *a drawing compiled by the Subcommittee on Studio Facilities of the RMA (revised, October 9, 1946).*

[6] *A. V. Bedford and J. P. Smith,* "A PRECISION TELEVISION SYNCHRONIZING SIGNAL GENERATOR," *RCA Rev., Vol. 5, pp. 51-69; July, 1940.*

cuit restores the picture signal to some arbitrary reference level at the end of each scanning line; *i.e.*, during the retrace or blanking period. It is independent of anything that takes place in the signal. Thus no surge can exist longer than the period of one line.

The field switching system is a suitcase unit of the same shape and size as the other units described previously (Figure 2-14). On the

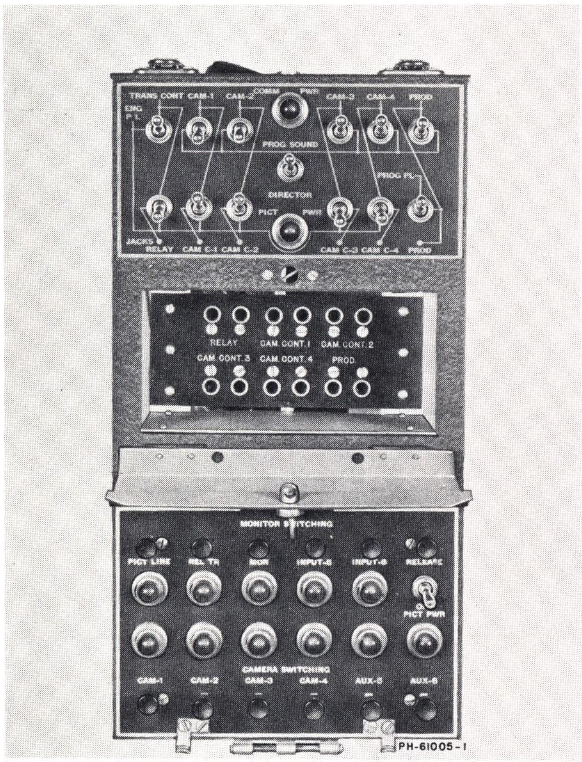

Figure 2-14 - Field Switching System, Front Side

front panel are located two sets of push-button switches, the lower one of which provides for switching among four cameras and two auxiliary picture circuits. Each of these buttons has an associated tally light which operates in conjunction with tallies on the respective camera and camera control selected by it. These six switches connect six coaxial 75-ohm lines, one at a time, to the input of the picture amplifier contained in the unit.

The picture amplifier consists of three stages, the last one being a cathode follower which feeds the picture line to the relay transmitter, or a line directly to the main studio (75-ohm coaxial). A blocking capacitor separates the line from the cathode, so that no direct current flows in the line. The grid of this cathode follower is subjected to the action of the clamp circuit. Hence, no surges appear on the outgoing line.

Two other coaxial lines also provide signal to other parts of the system. One of these is connected to a line monitor, or field master monitor. It is fed through a separate unity-gain amplifier contained in the switching system. The input of this amplifier may be switched with the upper set of push buttons to any of several points in the pickup equipment. The second line may be used to feed an additional monitor for the use of spectators or an announcer, or it may feed a stand-by relay transmitter. All three output lines carry identical signals.

The synchronizing signal is mixed with the camera signal in the switching system to form the final composite picture signal. The synchronizing signal is supplied to the switching system directly from the pulse shaper, and is coupled to the picture output line through a two-stage amplifier. Thus, the synchronizing pulses are always transmitted independently of the camera switching. In cases where picture signal already including the synchronizing pulses is being received over one of the auxiliary input circuits, the local synchronizing signal may be disconnected by turning a special switch on the front panel.

Keying signal for the clamp circuit is derived from the sync. signal. In cases where the incoming signal includes sync., the sync. is separated, as in a receiver, and delayed so that keying is done on the "back porch," *i.e.*, on the peaks of blanking just following the sync. pulses (see Appendix). In the usual case where the picture signal is received from a local camera chain, sync. is not present at the clamped grid; hence it is not necessary to delay the keying in order to clamp at black level. In either case, clamping is done automatically at black level.

Circuits are included in the switching system for communication between the various technicians operating the equipment. Two sets of telephone jacks are mounted in each camera, one for the cameraman and the other for a program assistant stationed at the camera. Connections for these telephone sets are included in the camera cable. These intercommunication circuits all terminate in the field switching system where the technicians operating the camera controls and switching system, and the program director may connect their telephone sets. Private telephone lines to the main studio also terminate here, and may be connected to the local circuits. A variety of communication network combinations may be secured with the set of toggle switches on the upper front panel.

Each telephone set consists of a carbon-button microphone and two earpieces. The microphone and one ear-piece are used for the intercommunication circuits. The second earpiece is connected to a separate circuit which carries program sound. Thus, each operator can hear the program sound at all times, and get useful cueing information from it.

Power for operation of the telephone circuits is obtained through a selenium-disk rectifier from the power lines, and is entirely independent of the power for the picture-amplifier circuits.

FIELD MASTER MONITOR

A high-quality picture monitor primarily designed for studio applications has been adapted for use with the field equipment by the design of a special carrying case. (See Figure 2-2.) This monitor contains a 10-inch, nearly flat-faced kinescope with aluminum backing (type 1816P4), and a 5-inch oscilloscope tube. The kinescope, which operates at about 9000 volts, provides an exceptionally bright picture suitable for program monitoring in high levels of ambient illumination. The oscilloscope provides a large, clear trace of the outgoing picture signal, and associated circuits include means for accurate calibration of signal level. As indicated in Figure 2-1, the monitor is operated on the same power supply as the field switching system.

The shape of the master monitor case is somewhat different from the shape of the other suitcases because of the size of the tubes used. However, the dimensions and weight are of the same order.

APPENDIX

Two unusual circuits which contribute to the satisfactory performance of the field equipment are described in some detail in the following paragraphs. One of them has been discussed in a previously published article,[7] but will be reviewed here in the light of its direct applications in this equipment.

CLAMP CIRCUIT - As applied in television, a clamp circuit is a device for establishing an arbitrary reference potential at fixed and regular intervals on some chosen circuit element in the picture amplifier. The operation of establishing such an arbitrary reference is very useful wherever it is desirable to restore the d-c component of the picture signal, or, in other words, to make the actual "black level" in the signal coincide with an arbitrary reference. The clamp circuit is capable of doing this with an unusual degree of accuracy. It is a pulse-driven switching circuit, and is applicable only in cases where there are pulse intervals present in the amplifier signal during which the switching operation can take place. Since a television picture signal (having blanking pulses to suppress the scanning beam during the retrace periods) is of this type, the clamp circuit may be used successfully.

The orthicon and image-orthicon tubes both employ low-velocity scanning. Because of this, they generate picture signals which contain accurate black-level information during the blanked retrace periods. However, because these signals are generated at low level, the blanking pulses, which contain the "black-level" information, may include noise and other spurious components which make the pulses unsuitable for blanking in the receiver. This condition is

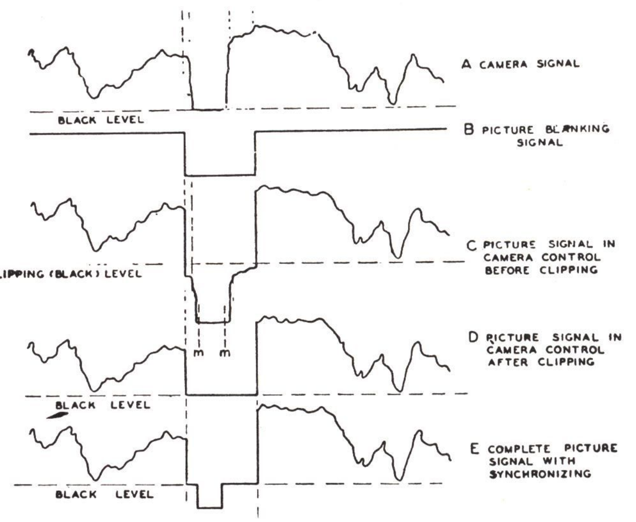

Figure 2-15 - Television Signal Wave Forms

illustrated in Figure 2-15(a). To provide clean-cut blanking pulses in the final signal, it is customary to add another blanking signal (Figure 2-15(b)) at a high-level point in the amplifier, giving the result shown in Figure 2-15(c). Then this composite signal is clipped at black level to give the signal shown in Figure 2-15(d). To insure proper operation of the receiver, the clipping must be done accurately at black level. Here the clamp circuit is an indispensable tool. It is used to bring

[7] C. L. Townsend, "THE CLAMP CIRCUIT," *Broadcast Eng. Jour.*, February and March, 1945.

about a firm correlation between the black level existing in the negative peaks of the camera blanking pulses and the grid bias on the clipper stage of the amplifier. It should be noted that the addition of a constant signal (such as the blanking signal shown in Figure 2-15(b)) does not affect the accuracy of the correlation between black level and clipper bias, but simply shifts the bias to a new value.

A simplified diagram of an amplifier controlled by a clamp circuit is shown in Figure 2-16. It consists of two amplifier tubes, V_1 and V_2, with a clamp circuit, consisting of the switch S in series with a small resistance R, connected to the control grid of V_2 on which it operates. Whenever the switch S closes, the grid of V_2 is established at the potential of terminal P (which is the arbitrary reference potential), provided that S is closed for a time interval that is long compared to the time constant $(R + R_L)C_1$. This latter condition is necessary for proper operation of the clamp circuit.

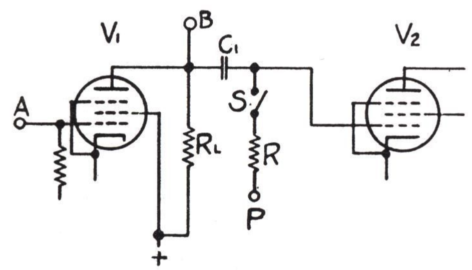

Figure 2-16 - Simplified Schematic Diagram of Clamp Circuit

Assume that the camera signal of Figure 2-15(a) has been introduced at terminal A in Figure 2-16, and the blanking of Figure 2-15(b) at terminal B, but with polarities such that the resultant mixed signal as shown in Figure 2-15(c) appears on the plate of V_1. Now let the switch be closed for intervals such as m-m included within the peak of each camera blanking pulse, and let it be open the rest of the time. Thus the grid of V_2 is established firmly at the potential P at each peak of the camera blanking. The tube, V_2, is made part of a clipper or limiter, hence, when P is set at the proper value with respect to the cut-off potential of the clipper grid, the clipping will take place at black level.

In actual practice, the switch is a pair of diodes (contained in the twin diode, V_3) which are keyed on and off by equal pulse signals of opposite polarity, as shown in Figure 2-17. These two pulse signals are coincident with

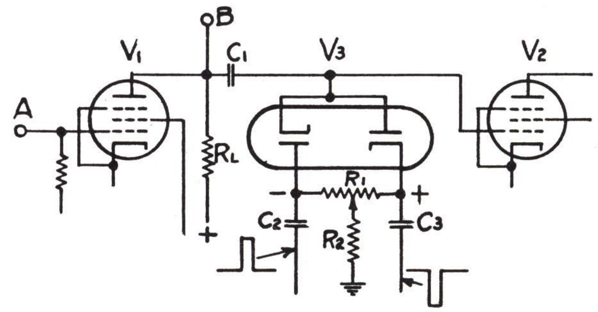

Figure 2-17 - Schematic Diagram of Clamp Circuit

each other and also with the time interval m-m in Figure 2-15(c). Thus, both diodes conduct simultaneously and provide a low-impedance path for current flow to change the charge on C_1. In this case, the critical time constant is

$$\left(R_L + \frac{R_D}{2} + R'\right) C_1$$

where R' is the effective resistance of the signal source which generates the keying pulses, and R_D is the effective resistance of one diode. In most cases, C_1 is made about 500 $\mu\mu fd$ and the total resistance about 2500 ohms. Hence, the time constant of the circuit is about 1.25 microseconds. Since the total keying interval is usually about 6 microseconds, there is time for the charge on C_1 to approach equilibrium.

In Figure 2-17, the reference potential is that which exists at the midpoint of R_1. This may be deduced as follows. During the keying-pulse intervals, both diodes conduct, and hence both terminals of R_1 are at the same potential. Because of this conduction, the equal capacitors, C_2 and C_3, receive opposite charges, each equal to the peak-to-peak voltage of the pulses. During the intervals between pulses, the diodes become nonconducting, and the charges placed on C_2 and C_3 cause a current to flow in R_1, producing a voltage drop equal to the sum of the pulse voltages on the two capacitors. The polarity of the voltage is shown in Figure 2-17. Since both the circuit and keying signals are balanced, it is then apparent that the diodes always arrive at a single potential during the pulse intervals which is the same as the potential existing at the midpoint of R_1 during the intervals between pulses. The time constant $C_2R_1 = C_3R_1$ is made very large compared to the period of the pulses, so that the current in R_1 is small; hence the charges on C_2 and C_3 remain essentially constant.

If R_1 is connected as a potentiometer, as shown in Figure 2-17, the reference potential (at the midpoint) may be shifted with respect to ground. For example, if the control is moved to the left, the midpoint becomes positive with respect to ground. This control is an effective and useful means of adjusting the bias on the grid of the amplifier tube, V_2. Whenever the control is moved away from the midpoint the circuit becomes unbalanced, and difficulty may be experienced in maintaining pulse shape, especially when the control is near one end of R_1. To minimize this effect, a resistor, R_2, may be inserted in the ground connection. Since the average current in such a resistor is always zero, it may have a very large resistance. Use of this control in no way disturbs the accuracy of the clamping action in establishing the grid of V_2 at the reference potential (midpoint of R_1).

The only path for charging current from the capacitor C_1 (in the absence of grid current in V_2), is through the clamp circuit. During the open-circuit intervals in the clamp circuit, it is therefore impossible for the charge on C_1 to change. Hence the low-frequency response of the coupling circuit between V_1 and V_2 is not attenuated even though the capacitance of C_1 be made very small.

It is important that the keying interval *m-m* shall come to an end *before* the end of the blanking pulse, so that the charge which is left on C_1 will always correspond to black level in the picture signal, and not to some other level existing in the signal after the blanking pulse.

A further consideration is necessary in determining the proper value for the time constant

$$\left(R_L + \frac{R_D}{2} + R'\right) C_1.$$

The peaks of the camera blanking pulses usually contain some high-frequency noise signal originating in the low-level parts of the signal system. The response of the charge on C_1 to the clamping action must be slow compared to the period of the noise signal, in order to avoid variations in the correlation between black level and the reference potential. Black level may be considered as the average of the noise signal. Hence the clamp must be slow enough to average out the noise. Since the resistive elements are usually determined by the requirements of the keying circuits, the value of C_1 is used to control the time constant. Values cited previously have been found to work well is most cases, though where the noise signal contains low-frequency components it may be necessary to use a larger value for C_1.

The chief advantage in the clamp circuit, as compared to other types of leveling or d-c restoring circuits, is the fact that its action is entirely independent of the picture signal in the amplifier. It depends only on the keying pulses. These may be controlled at will with respect to amplitude and timing. It should be noted that the amplitude of the keying pulses is usually made about twice the amplitude of the picture signal in the amplifier at the point where the clamp operates.

The ability to control the time at which the clamping is done is sometimes of great advantage. For example, in the field switching system, it is necessary to clamp the signal after the camera switching. At the point where the clamping is done, it is necessary to accommodate two types of picture signal: (a) from the cameras, in which case the sync. pulses are not present, since they are added subsequently, and (b) from an outside source which provides complete composite signal including the sync. pulses. Clamping must be done on the same level in both types of signal. Obviously, clamping cannot be done on the peaks of sync. in case (a); hence, it just be done on blanking peaks, or at true black level, which is present in both cases.

In case (b), the only available space on which the clamp may operate at black level is that portion of the blanking pulse immediately following the sync. pulse, commonly called the "back porch" (see Figure 2-18). Keying pulses are derived from the sync. by separation as in a receiver, and subsequent forming. A sync. pulse after separation is shown in Figure 2-18(b). This separated signal is fed to the grid of a triode as in Figure 2-19. The capacitor C is made very small, about 20 $\mu\mu fd$ and the grid leak R is connected to a positive voltage source. Before the leading edge of the pulse, it may be assumed that the grid is drawing current, hence is approximately at cathode potential. The positive excursion of the leading edge causes very little change in the grid potential because of the low impedance from grid to cathode. The resulting sharp exponential pulse is shown in Figure 2-18(c). After returning to its original potential, the grid is excited by the trailing edge of the pulse in the negative direction. This excursion stops the flow of grid current and also swings far enough to go beyond plate-current cut-off, as illustrated. The signal voltage causes no further change, but the positive voltage on the grid leak immediately starts to recharge the

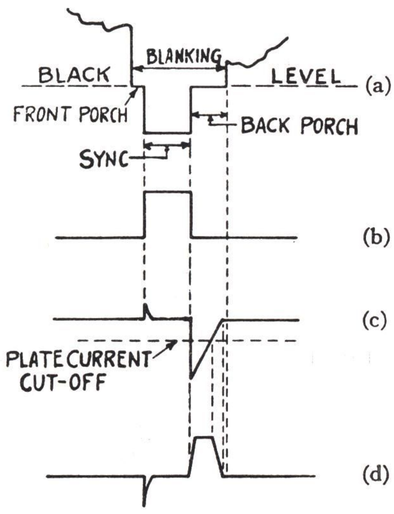

Figure 2-18 - Derivation of Keying Pulses for Back-porch Clamping

capacitor C, and thus produces the positive slope shown in the diagram. The rise in grid voltage stops abruptly as soon as grid current starts to flow. The steepness of this slope is proportional to the position bias voltage, and inversely proportional to the value of R. Hence the duration of this negative sawtooth may be adjusted by changing either the positive bias or the resistance of R.

The pulse of voltage appearing on the plate of the triode is shown in Figure 2-18(d). The leading edge of this pulse may be sloped a little to acquire some delay, by making R_L large and thus allowing the stray capacitance on the plate circuit to integrate the slope. Further

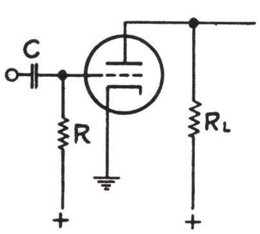

Figure 2-19 - Schematic Diagram of Differentiating Circuit

[8] *RCA Laboratories, Princeton, N. J.*

clipping of this signal eliminates the negative "pip" caused by the leading edge of the original pulse, and makes it suitable for a keying signal in a clamp circuit to operate on the "back porch."

Examination of the functioning of this circuit during the serrated vertical pulse in the standard RMA sync. signal shows the formation of keying pulses which are timed to coincide with the slots in the vertical pulse. Thus keying of the clamp circuit at black level is carried on with no interruption throughout the vertical sync. pulse.

Use of this type of clamp circuit in the switching system eliminates surges introduced by switching, and also any surges and low-frequency additive cross talk from other sources which may have been introduced ahead of the clamping point. It further insures constant sync. output under all conditions of varying picture signal by confining the sync. pulses to a fixed portion of the e_g - i_p characteristic of the output stage.

CLIPPER CIRCUIT - The clipping operation required in the process of correlating the peaks of blanking pulses with black level, illustrated in Figure 2-15, must be performed with rigid accuracy. In order to maintain the clipping level with the necessary accuracy, it is imperative that the critical electrode in the clipper stage be controlled by a clamp circuit, as described in the preceding paragraphs. When as is usually the case, a screen-grid tube is used as a clipper, it is further necessary to supply current to the screen grid from a regulated source so that its potential does not change with variations in the average brightness of the scene. With these two precautions, any of the usual types of clipper will maintain the correct black level in the blanking pulses.

The clipper circuit used in the field equipment has unusual characteristics which merit description. It is a circuit which was developed originally by K. R. Wendt[8] to overcome the inherent curvature near cut-off in the plate-current-cutoff type of clipper. Such curvature increases the gamma of the system. Since the orthicon type of camera tube has unity gamma, and the average kinescope has gamma in the neighborhood of 2, the resultant system gamma is higher than is ordinarily desired. Therefore, it is desirable to avoid increasing the gamma at any other point in the system.

The basic circuit (Figure 2-20) includes a pentode amplifier, V_2, which has for its principal plate load a resistor R_2 in series with a diode, V_4. An additional load, R_1, is connected in parallel with R_2 and V_4. R_1 is much larger than R_2. The diode acts as a peak limiter, preventing the flow of current in R_2 whenever its cathode rises above the potential $E_b/2$. The tube, V_2, is the same as V_2 in the previous Figures 2-16 and 2-17, with its control grid connected to a clamp circuit. Both of the supply voltages shown, E_b and $E_b/2$, are closely regulated and have approximately the 2-to-1 relationship indicated. Under these conditions,

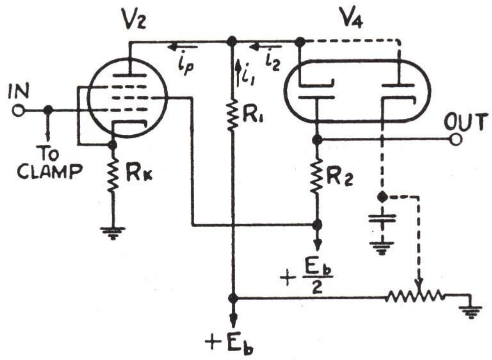

Figure 2-20 - Schematic Diagram of Linear Clipper

black level will correspond to some definite value of plate current in V_2. By adjusting the clamp reference potential (equivalent to adjusting the bias on V_2) to the proper value, black level may be made to coincide with point B in Figure 2-21.

The curve A-B-D represents the normal $e_g - i_p$ curve of V_2. From A to B, no current flows in R_2 and hence $i_p = i_1$. However, between B and D, current flows in V_4 and R_2, and hence i_p divides itself between R_1 and R_2. Therefore $i_p = i_1 + i_2$ in this region of the curve. By proper selection of the value of R_1, it is possible to place point B (cutoff point of the diode, V_4) so that B-D covers the linear portion of A-B-D. Then at all times the useful part of the picture signal swings only over this linear part of the tube characteristic. The curved portion of the characteristic from A to B is not used, and hence does not affect the gamma of the system.

It should be noted that the cutoff of this circuit is extremely abrupt. This arises from the fact that V_2 is a screen-grid tube having a very high plate resistance. In other words, the flow of plate current is not influenced appreciably when the external load resistance is changed by the opening of the diode. Therefore, as i_2 approaches zero, the ratio i_1/i_2 rises very rapidly, and, since R_1 is large (about 20 to 20 times R_2), the potential of the cathode of V_4 also rises very rapidly, carrying the diode abruptly through its cutoff region.

The diode limiter, V_4, has one serious fault; namely, its plate-cathode capacitance permits feed-through of unwanted parts of the signal - particularly, steep wave fronts involving high frequencies. This trouble may be largely nullified by the simple device of connecting a second diode (available in any of the twin diodes) across the plate circuit of V_2, as shown by the dotted lines in Figure 2-20. By proper adjustment of the bias control on this diode, it may be made to start conducting at a potential just above the cutoff potential of the limiter diode, thus causing a low-resistance

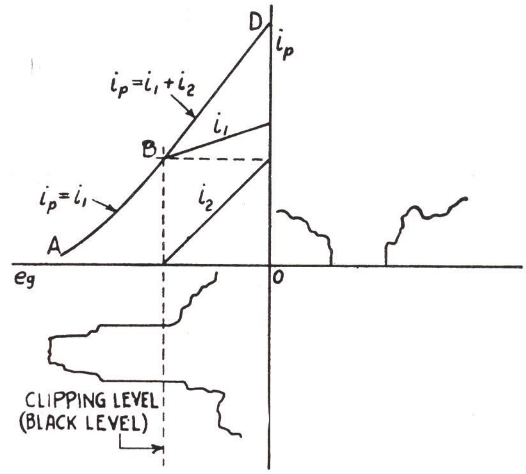

Figure 2-21 - Characteristic Curve of Linear Clipper

shunt to appear across the signal source which effectively "squelches" the signal and prevents feed-through.

ACKNOWLEDGMENT

The equipment described in this paper is the result of the combined efforts of a large number of engineers with whom the writer has been associated during the past decade. Development of a workable system embracing so many complex circuits cannot be ascribed to the abilities and judgment of one or two, or even a few, persons. It is necessarily the product of the thinking of many individuals working collectively on the various problems. Among these are M. A. Trainer, W. J. Poch, H. N. Kozanowski, G. L. Beers, N. S. Bean, J. M. Brumbaugh, H. M. Potter, and F. E. Cone, of the RCA Victor Division, Radio Corporation of America, Camden, N. J., and R. D. Kell, A. V. Bedford, J. P. Smith, K. R. Wendt, and A. C. Schroeder of the RCA Laboratories Division, Radio Corporation of America, Princeton, New Jersey.

TELEVISION TECHNICAL TRAINING PROGRAM

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SECTION III

TERMINAL EQUIPMENT THEORY

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TELEVISION TECHNICAL TRAINING PROGRAM

TERMINAL EQUIPMENT THEORY
THE TELEVISION SYSTEM

PART I

A REVIEW OF THE BASIC CONCEPTS OF THE SYSTEM AND THEIR EFFECT ON THE DESIGN OF STUDIO EQUIPMENT

INTRODUCTION

The problems which arise in the design of television equipment involve a branch of electronics which is strange to many technicians entering the field for the first time. This is especially true of those who have long experience in the field of sound broadcasting and reproduction, but whose education and experience antedate the post-war television boom as well as the war-time period, during which were developed so many of the techniques of electronic pulsing circuits. Basically the art involves the generation and reproduction of high-speed transient phenomena at both regular and irregular intervals and the consequent need for understanding circuits used for amplifying and transmitting wide bands of frequencies. Not only are the techniques new, but a whole new language has been developed to aid in their expression. It is hoped to provide here at least a brief glimpse of this new field and its language, thus helping the beginner to a firmer grasp of the tools he must now employ.

LIMITATIONS

No true appreciation of any system can be realized without some understanding of its basic limitations, and a discussion of the television system should therefore begin by reviewing these. The most serious limitation of a television system, as in the case of an aural system, is "noise." The same phenomena that cause hum, crackle, and hiss in the background of a sound broadcast, cause bar-like shadows, random blotches, and "snow storms" in the background of a television picture. The word, noise, has been carried over from aural terminology into television terminology with the same connotation; thus, any spurious elements in a television picture are generally called noise. In reading the following discussions, it will be helpful to remember that much of the reasoning behind the methods used in the television system is based on the need to minimize the effects of noise.

Spurious noise components in the signal arise from three general sources, (a) shot noise and thermal agitation in vacuum tubes and other circuit elements, (b) pickup from associated or remote electrical apparatus, and (c) microphonics. The best means for minimizing noise is to maintain a high signal-to-noise ratio in all parts of the system; but where this is impossible, special circuits are a distinct aid in extending the useful range of operation.

Noise limits, among other things, the ability of the system to resolve fine detail. However, a more direct limitation on the resolving power of the system is the frequency bandwidth available in the transmission system. This limitation has commercial aspects of more significance than the technical aspects because of the limited room available in the radio spectrum. As a result, the decisions of the Federal Communications Commission effectively determine the limits of resolution within the noise-free service area of any station. Long years of field testing have shown that a six-megacycle channel will provide adequate resolution and at the same time will yield a reasonable number of channels.

Other factors which limit overall performance are the fineness of scanning apertures*, the degree of accuracy with which tonal gradations

** The use of the word aperture in television probably arose from the use of scanning disks where the light passed through small holes which traversed the projected area of the scene. Small holes traversing closely spaced lines in the area were capable of greater resolution than larger holes traversing more widely spaced lines. Though scanning disks are no longer used, the term aperture is still applied to the scanning device in a general sense. In electronic television, the diameter of the "aperture" is simply the diameter of the scanning beam of electrons in the plane of the scanned image. Similarly the term aperture correction is applied to means (usually the use of special circuits) for compensating the picture signal for loss of resolution caused by finite size of the beam and by non-uniform distribution of electrons over the cross-sectional area of the beam.*

are reproduced, and the brightness range of which the reproducing device is capable. However, if it can be assumed that the transmission system between the pickup and reproducing devices is reasonably linear, then the problems arising from these particular limitations are confined largely to the pickup and reproducing devices themselves, and do not affect system considerations to the same extent as limitations described in the preceding paragraphs, and as certain economic factors do.

Economic factors usually limit the degree to which technological development is used to improve the quality of performance. Methods may be known by which some of the physical limitations of the system can be overcome, but sometimes such methods are not used for a long time after their discovery because means for applying them economically are not developed simultaneously. In other words, their use increases the cost of equipment excessively. This is especially true in the case of receiving equipment which must be produced in large quantities at low unit cost.

Such methods often do find their way into transmitting equipment, where low unit cost is not so important and where quality of performance is paramount. Quality is stressed in transmitting equipment to provide reliability and to reduce the need for including in the receivers complicated and expensive corrective circuits. Examples are circuits for automatic correction of scanning linearity, and clamp circuits for accurate re-establishment of black level, or d-c restoration, as it is often called.

STANDARDS

During the decade preceding the entrance of the United States into World War II, Radio Corporation of America carried on an extensive program of research and development in television which has been largely responsible for the formulation of the standards governing our present black-and-white system. The earliest work on standards was done through the medium of the Radio Manufacturers' Association. Much more extensive work on standards was carried on later by the National Television System Committee and the Radio Technical Planning Board, the former body being set up to deal exclusively with television standardizing problems and to bring about agreement among the several interested groups on suitable standards for recommendation to the FCC. With the approach of commercial broadcast service, the FCC adopted the recommendations of these bodies as the basis for tentative standards of good operating practice. Activity of the RMA has continued on television and its recommendations have been extended to cover much of the detail of studio and transmitter operation, and of receiver design. While a considerable portion of this material still exists only in the form of recommendations to the FCC, it will undoubtedly constitute the major part of the final standards.

One of the most important standards recommended is the one which describes the waveshape of the picture signal. This standard is outlined in detail in a drawing which is reproduced in Figure 3-5. Reference will be made to this drawing from time to time in discussing the system, and an attempt will be made to clarify the reasoning involved in establishing many of the specifications included in it.

SCANNING SYSTEM

The standard system of scanning in television is one in which the scene or image is traversed by the aperture in lines which are essentially horizontal, from left to right, and progressively from top to bottom. The aim is to have the aperture move at constant velocity both horizontally and vertically during actual scanning periods because this type of motion is simple to duplicate in the reproducing aperture and because it provides a uniform light source in the reproducer. At the end of each line the aperture, or scanning beam, moves back to the start of the next line very rapidly. The time occupied by doing this is called the *fly-back* or *retrace* period. In a similar way, the beam moves from the bottom back to the top after the end of each picture scan. Motion during retrace periods need not be linear. The complete traversal of the scene is repeated at a rate high enough to avoid the sensation of flicker. This rate has been set at 60 times per second because most of the power systems in the United States are 60-cycle systems, and synchronism with the power system minimizes the effects of hum and simplifies the problem of synchronizing rotating machinery in the television studio (film projectors) with the scanning.

It has appeared rather recently that the choice of 60 cycles for the vertical scanning frequency was a fortunate one for another reason. The progress of the art has included means for obtaining brightness levels in the reproduced pictures which are appreciably greater than those used in motion picture theatres. It is well known that the threshold of flicker increases as the brightness increases. Thus, 48- or 50-cycle flicker would be noticeable to some observers at modern brightness levels in television receivers. Persistence of vision varies in different people, and those whose persistence characteristics are short are conscious of the 60-cycle flicker in the bright pictures on some present-day receivers. Therefore it appears that a still higher vertical frequency would be desirable if other factors would permit. Needless to say, the interline flicker, mentioned later in connection with interlacing, is also less objectionable with the higher scanning rate.

Another important factor affecting flicker is the persistence characteristic of the screen material in the receiver. This can be made long enough to overcome any appearance of flicker, even with scanning rates less than 50 cycles per second, but, if carried too far, such long persistence causes ghost-like trailing after moving objects in the scene. Judicious choice of screen persistence is a great aid in reducing flicker.

Obviously the scanning apertures in the pickup and reproducing parts of the system must be in exact synchronism with each other at every instant. To accomplish this, synchronizing information is provided in the form of electrical pulses in the retrace intervals between successive lines and between successive pictures. The retrace intervals are useless in reproducing picture information, hence are kept as short as circuit considerations permit, but are useful places in which to insert the synchronizing pulses. These pulses are generated at the studio in the same equipment that controls the timing of the scanning of the pickup tube, and they become part of the complete composite signal which is radiated to the receiver. Thus scanning operations in both ends of the system are always in step with each other. Synchronizing is discussed in more detail in a later section.

The number of scanning lines is the principal factor determining the ability of the system to resolve fine detail in the vertical direction. The number of scanning lines is also related to the resolving power in the horizontal direction because it is desirable to have the same resolution in both directions. Thus, as the number of lines increases, the bandwidth of the system must also increase to accommodate the greater resolution required in the horizontal direction. The present system employs 525 lines, a number arrived at after thorough consideration of the related questions of channel width and resolution by the N.T.S.C. and the R.T.P.B.

INTERLACING

One of the most interesting features of the television scanning system is the interlacing of the scanning lines, a scheme which is used to conserve bandwidth without sacrificing freedom from flicker. The sensation of flicker in a television image is related to the frequency of the illumination of the entire scene. It has no relation to the number of scanning lines nor to the frequency of the lines themselves. Therefore a system which causes the entire area of the scene to be illuminated at a higher frequency, even though the same lines are not scanned during successive cycles of illumination, results in greater freedom from flicker. Interlacing does just this by scanning part of the lines, uniformly distributed over the entire picture area, during one vertical scan, and the remaining part or parts during succeeding scans. Thus, without changing the velocity of the scanning beam in the horizontal direction, it is possible to obtain the effect of increased frequency of picture illumination.

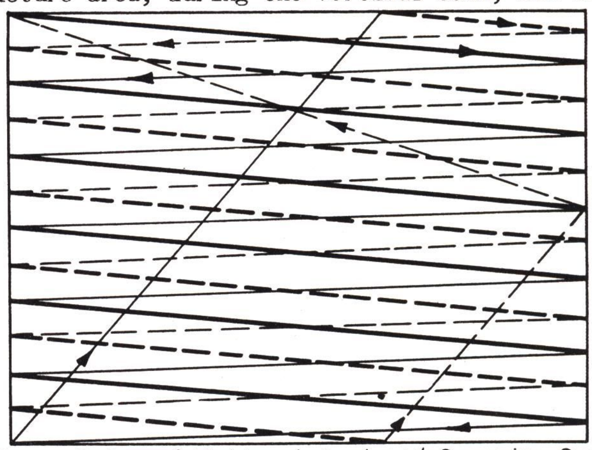

Figure 3-1 - Odd-line Interlaced Scanning System with 13 Lines. Consecutive Fields are Indicated by Solid and Dotted Lines, Respectively.

In the standard two-to-one interlaced system, alternate lines are scanned consecutively from top to bottom, after which the remaining lines, that fall in between those included in the first operation, are likewise scanned consecutively from top to bottom. (Figures 3-1 and 3-2 il-

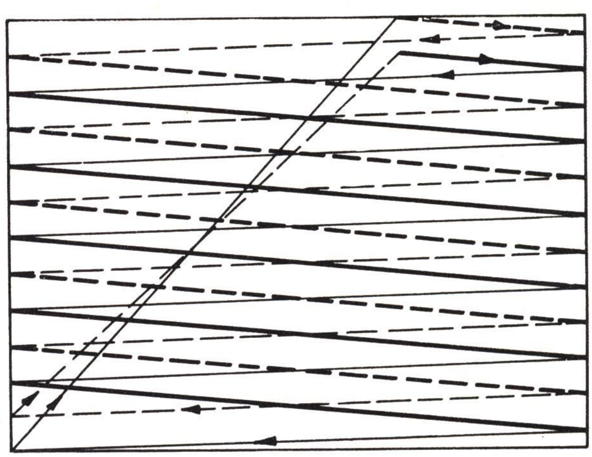

Figure 3-2 - Even line Interlaced Scanning System with 12 lines.

lustrate this principle). In the 525-line system, each of these groups, called a *field*, consists of 262-1/2 lines. Two consecutive fields constitute a *frame*, or complete picture, of 525 lines. Each field is completed in 1/60 of a second and each pair of fields or frame, in 1/30 of a second. The effect on the observer's eye, from the standpoint of flicker, is that of repetition of screen illumination every 1/60 of a second, yet the complete picture is spread out over 1/30 of a second.

The important result of interlacing is a reduction in the bandwidth of the frequencies generated in the picture signal, for a given value of limiting resolution, as compared to the bandwidth produced in a system using sequential scanning. This may be understood as follows. In either system, interlaced or sequential, the vertical scanning frequency must be the same and must be high enough to avoid the sensation of flicker. In the standard television system this frequency is 60 cycles per second. In a sequential system, *all* of the scanning lines must be traversed in the basic vertical scanning period. However, in the two-to-one interlaced system, only *half* of the scanning lines are traversed in the same period. Thus, obviously, the horizontal velocity of motion of the aperture in the interlaced system is only half of the velocity in the sequential system, and likewise the signal frequencies are reduced by the same factor.

Interlaced scanning has certain inherent faults among which are interline flicker, and horizontal break-up when objects in the scene move in the horizontal direction.

Interline flicker results from the fact that adjacent scanning lines are separated in time by 1/60 of a second, and that each line is repeated only at intervals of 1/30 of a second, It is apparent in any part of a scene where some detail of the scene is largely reproduced by a few adjacent scanning lines, and where the contrast in the detail is high. For example, the top edge of a wall which is oriented in the scene so as to be nearly parallel to the scanning lines might be reproduced by only two or three adjacent lines. The 30-cycle flickering of the line segments forming the edge of the wall would be quite noticeable. In the limiting condition, where the wall is exactly parallel to the scanning lines, the edge would be reproduced by only one line repeated at intervals of 1/30 of a second. This is probably the worst possible condition, but one which is encountered rather infrequently. The top and bottom edges of the raster nearly always produce objectionable interline flicker because they are nearly parallel to the scanning lines. Interline flicker, like any other type of flicker, is most objectionable in scenes where the highlights are very bright and the contrast is high. When the brightness and contrast are low, interline flicker becomes negligible.

Break-up exists when an object in the scene moves in the horizontal direction rapidly enough so that the total motion in 1/60 of a second is equal to one or more picture elements. Then vertical edges of the object become jagged lines instead of smooth lines and there is apparent loss in horizontal resolution. This is roughly illustrated in Figure 3-3 where two rectangles

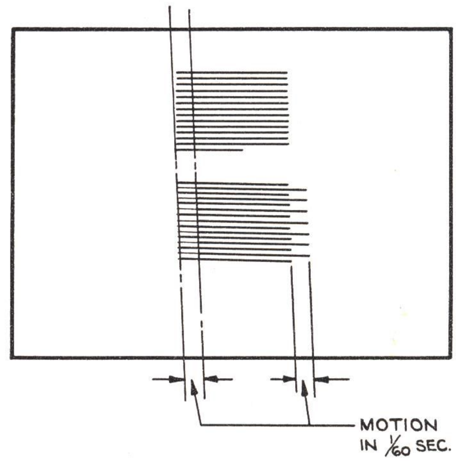

Figure 3-3 - Effect of Horizontal Motion on Resolution of Vertical Edges in 2-to-1 interlaced System. Upper Object Stationary. Lower Object Moving to Right.

are shown, the upper one being stationary, and the lower one moving toward the right. The moving rectangle is shown as though it started moving from a position directly below the other. In the moving rectangle, signal is generated, *in both fields*, from the starting position of the left edge because of the storage of information in the pickup tube during the interval between fields. Thus the storage effect causes actual blurring of the trailing edge of a moving object. This is illustrated by the thin extensions of the scanning lines in the second field at the left side. The leading edge of the moving object may have a more definite jagged appearance because the storage effect in the pickup tube cannot fill in the spaces. In nonstorage pickup devices, both edges will appear jagged.

The geometrical distortion, illustrated by the tendency for the moving rectangle to become rhombic, is characteristic of any scanning system, whether interlaced or sequential. It is similar to the effect produced by a focal-plane shutter in a photographic camera.

Further consideration makes it clear that higher ratios of interlacing would produce these troubles in aggravated form, which would be intolerable. Another objection to higher ratios of interlacing is an illusion of crawling of the scanning lines either up or down, depending on motion of the observer's eyes. The effect is extremely annoying and tends to distract the observer's attention from the scene.

The type of interlacing adopted for commercial television is known as *odd-line* interlacing. The total number of lines is an odd integer. Thus the number of lines in each of two equal fields is a whole number plus a half. In this system, the use of perfectly uniform vertical scanning periods (equal to half the product of the total number of lines and the period of one line) and constant vertical scanning amplitude, results in consecutive fields which are displaced in space with respect to each other by half a line, thus producing interlacing of the lines, as illustrated by the 13-line system in Figure 3-1. Specifically, as stated above, the total number of lines in the standard system is 525; the number per field is 262-1/2; the vertical scanning frequency is 60 cycles per second; the number of complete pictures (frames) per second is 30; and the horizontal scanning frequency is 60 x 262-1/2, or 15,750 cycles per second.

Interlacing may also be obtained when the total number of lines is an *even* number, but *even-line* interlacing requires that alternate fields be displaced vertically one-half line with respect to each other by the addition of a 30-cycle component to the amplitude of the vertical scanning sawtooth wave (see Figure 3-2). This frame frequency component must have a degree of accuracy that is impractical either to attain or maintain. Hence even-line interlacing is not used for commercial television.

One other factor has influenced the choice of the particular number of scanning lines. This is the need for an exact integral relationship between horizontal and vertical scanning frequencies. It has been the practice to attain this relationship by using a series of electronic counting circuits. To secure a high degree of stability, the characteristic count of each circuit was limited to a small integer less than ten. Thus the h/v frequency ratio was required to be related to the combined product of several small integers. In the RCA synchronizing generator equipment, for example, there are four such circuits counting the numbers 7, 5, 5, and 3 respectively. The combined product of these four numbers is 525, the number of lines per frame. The product of 525 and 60 is 31,500 which is the frequency of the master oscillator in the sync generator. To obtain the correct frequency for the horizontal scanning system, another counter circuit divides the master oscillator frequency by two to yield the required frequency of 15,750 cycles.

SYNTHESIS OF THE PICTURE SIGNAL

The basic part of the signal applied to the reproducer is the series of waves and pulses generated during the actual scanning lines in the pickup or camera tube. No matter what else is done in the equipment intervening between the two ends of the system, this basic part of the signal should be preserved in character with the greatest possible accuracy. However, during the retrace periods, the pickup tube may generate signals which are spurious or which at least do not contain valuable picture information. Furthermore, retrace lines in the reproducing tube itself, especially during vertical retrace, detract from the picture. It is therefore desirable to include in the picture signal, components which will eliminate spurious signals during retrace and the retrace lines themselves in the reproducer. These results may be obtained by adding synthetically some pulses known as blanking pulses.

Blanking pulses are applied to the scanning beams in both the camera tube and the kinescope in the receiver. *Camera blanking* pulses are used only in the pickup device and never appear directly in the final signal radiated to the receiver. They serve to close the scanning aperture in the camera tube during retrace periods. In orthicon tubes, the picture signal during retrace thus goes to reference black or to some level constantly related to reference black. This is a useful result to be discussed later. In iconoscopes, no such constant relationship to black exists during retrace, and the only function of camera blanking is to prevent spurious discharge of the mosaic during the retrace periods.

Kinescope blanking or *picture blanking* pulses are somewhat wider than corresponding camera blanking pulses. They become integral parts of the signal radiated to the receiver.

The function of the kinescope blanking pulses is to suppress the scanning beam in the kinescope (reproducing tube), or in other words, to close the aperture in the receiver during the retrace periods, both horizontal and vertical. They are simple rectangular pulses having duration slightly longer than the actual retrace periods in order to trim up the edges of the picture and eliminate any ragged appearance. They are produced in the sync generator from the same basic timing circuits that generate the scanning signals; hence they are accurately synchronized with the retrace periods. Typical waveshapes of a basic camera signal and blanking pulses are illustrated in Figure 3-4, A and B respectively. Only parts of two scanning line periods are shown, and the pulse in B is therefore a single *horizontal blanking pulse.* The result of adding the signals in A and B is shown in C, where it

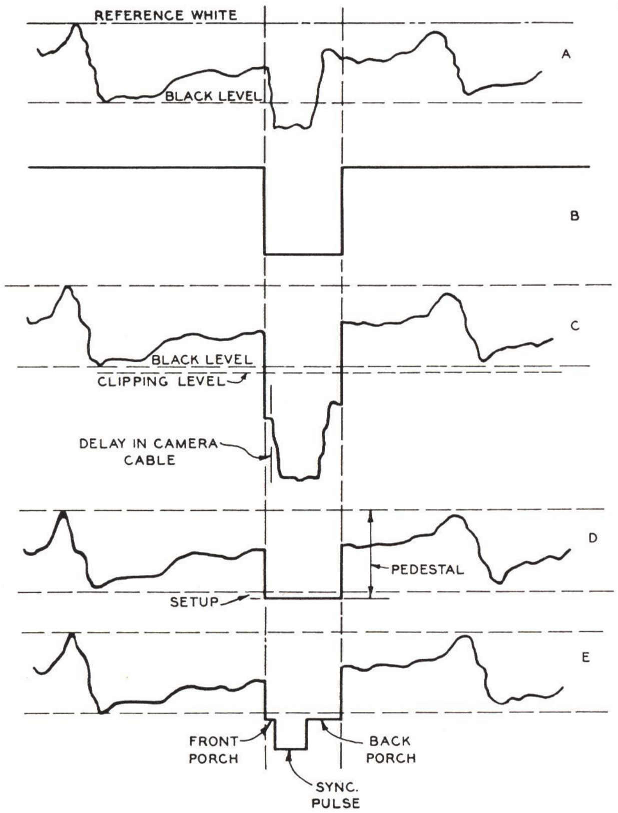

Figure 3-4 - Steps in Synthesis of Picture Signal.

may be seen that the unwanted spurious part of the camera signal has been pushed downward out of the territory of the basic picture signal. This unwanted part may now be clipped off and discarded, leaving the signal illustrated in D.

The blanking signal, shown only in part in Figure 3-4B, actually contains pulses for removing visible lines during both horizontal and vertical retrace periods. The horizontal pulses recur at intervals of 1/15,750 of a second and are only a small fraction of a line in duration; but at times corresponding to the bottom of the picture they are replaced by *vertical blanking pulses* which are just like the horizontal pulses, except that they are of much longer duration, approximately 15 scanning lines long, because the vertical retrace is much slower than the horizontal. The period of recurrence of the vertical blanking pulses is of course 1/60 of a second. Both horizontal and vertical blanking pulses, and their approximate relationship, are shown in diagrams 1 and 2 of Figure 3-5.

The picture signal shown in D of Figure 3-4 may be considered as partly natural and partly synthetic. It is important to point out here that the natural part, or basic camera signal, may contain certain noise components arising from the fact that the output of the pickup tube usually is not large compared to the noise threshold of the first picture amplifier stage or some other part of the system, such as the scanning beam in an image orthicon. On the other hand, the blanking pulses, or synthetic parts of the signal, are added at a relatively high-level part of the system and are therefore noise-free (at least in the transmitted signal). The importance of noise-free blanking pulses will become apparent in the discussions of other functions which they perform.

Details of horizontal blanking pulse shape are shown in diagram 5 of Figure 3-5. That part of the diagram below the point marked Blanking Level is a synchronizing (sync) pulse which will be considered later. The overall vertical dimension β is the maximum height of a blanking pulse. Thus the top horizontal line is Reference White Level, as indicated in diagram 3. The duration, or width, of the pulse must be sufficient to cover the horizontal retrace in the most inefficient receiver. Thus, the circuit limitations in such receivers set a minimum limit to the horizontal blanking width which was the basis for the RMA specification in Figure 3-5. This minimum is indicated by the width near the peak (lower end) of the pulse and is prescribed by the sum of two dimensions $x + y$, the value of which is 16.5% of the horizontal period, H. The impossibility of producing infinitely steep sides on the pulse is recognized in the greater maximum width (18% of H) allowed at the upper end of the pulse and in the obviously sloped sides.

Because of inevitable discrepancies at the extremes of the sides of the pulse, all measurements of pulse widths are made at levels slightly removed from the extremes of the sides. These levels are shown by dotted horizontal lines in diagram 5 of Figure 3-5, spaced 10% of β from top and bottom of the pulse.

Details of the vertical blanking pulses are shown in diagrams 1 and 3 of Figure 3-5. The width of the pulses is not limited by circuit considerations, as is the width of horizontal blanking. The limitation here is the requirement of television film projectors of the intermittent type, that the scene be projected on the pickup tube only during the vertical blanking period. The maximum period of 8% is ample for the operation of present-day film pickup systems, the criterion being that enough time must

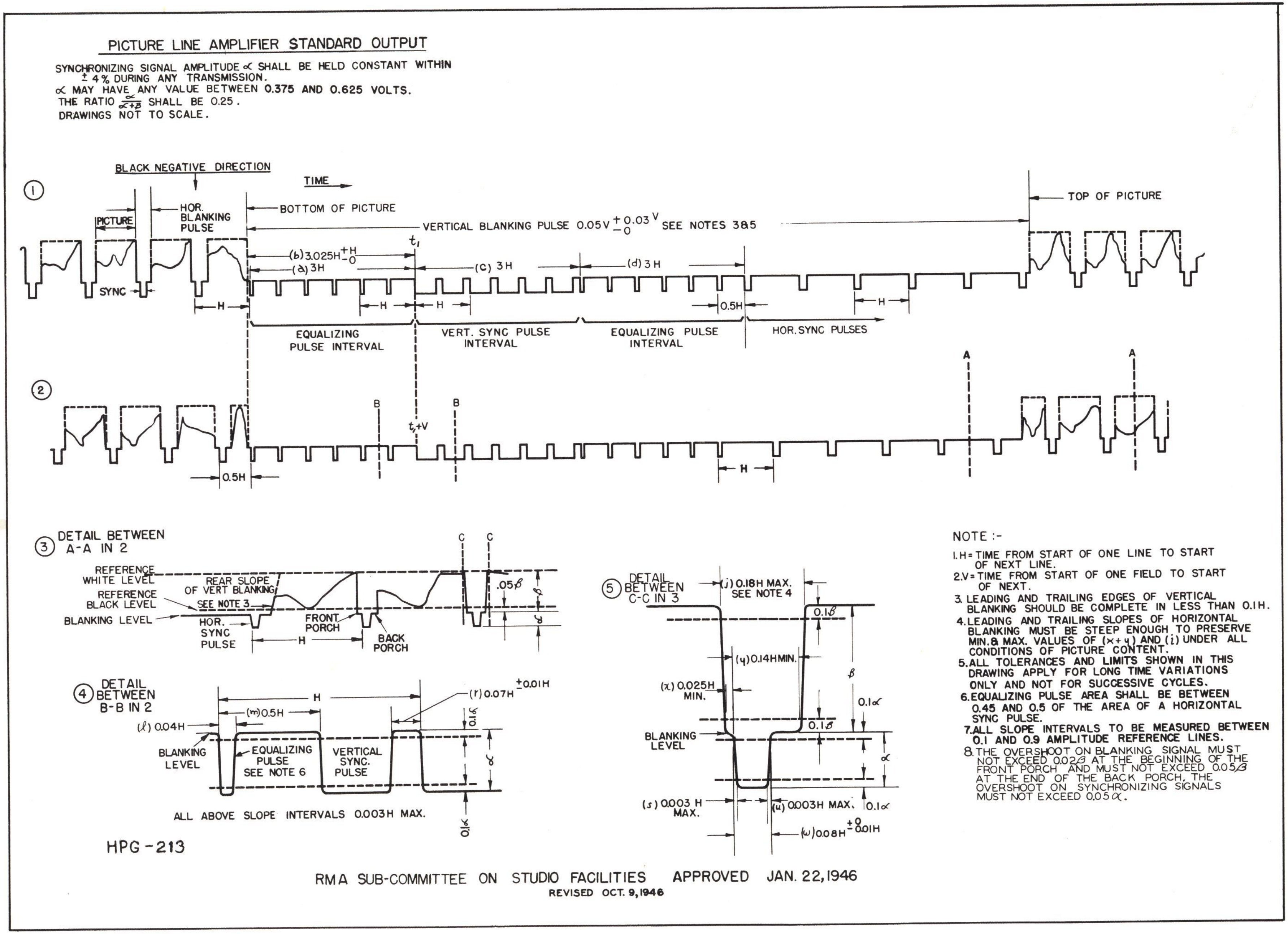

Figure 3-5 - Standard Television Signal be allowed for projection so that there is adequate storage of photoelectric charges on the sensitive surface of the pickup tube. The minimum period of 5% is an indication of expected system improvements in the future, when it will be possible to reduce waste of picture transmission time in vertical blanking. The present usefulness of the 5% minimum is to require receiver manufacturers to maintain vertical retrace periods at less than 5% and thus avoid the need for modifying old receivers when improvements are made in the system. The problem of film projectors is discussed in a later section.

The final step in synthesizing the complete composite picture signal which goes to the modulator in the transmitter is to add the synchronizing pulses which are required for triggering the scanning circuits in the receiver. These pulses, like blanking pulses, are essentially rectangular in shape. The blanking pulses serve as bases or pedestals (inverted) for the sync pulses, as shown in E of Figure 3-4. Here is one of the most important reasons for having noise-free blanking. The synchronizing function in the receiver is a very critical one, and it is important that nothing be allowed to distort the sync pulses either in shape or timing, as noise during the blanking intervals would do. The nature of the vertical sync signal is rather complicated; it is not illustrated in Figure 3-4, but will be discussed later along with other details of synchronizing.

The sync signal is not added individually to the output of each camera, but is added at the studio output so that switching from one camera to another will not cause even momentary interruptions in the flow of synchronizing information to the receivers.

THE D-C COMPONENT OF THE PICTURE SIGNAL

The visual and aural senses differ in one important respect which places a requirement on the television transmission system which has no counterpart in the sound transmission system. The response of the ear to sound is actually a response to variations in air pressure. While the ear is very sensitive to rapid variations in pressure, it is completely unconscious of absolute values of air pressure, or of slow variations in pressure, as sound. In other words, there is a definite low limit to the frequency of pressure variations which the ear accepts as sound. Therefore there is no need, for a sound transmission system, to pass frequencies below the aural limit which is somewhere in the neighborhood of 15 cycles per second. The circuits may be a-c coupled without loss of essential information. Even the best of practical systems have a low-frequency cutoff at about 30 cycles, and most others cut off somewhere between 50 and 100 cycles.

The eye, on the other hand, is sensitive to absolute intensities of light and to slow variations of intensity. As the frequency of variation increases, the eye rapidly loses its ability to follow the changes and tends to produce a sensation which is an average of the variations. It is this averaging ability that enables the eye to interpret a rapid succession of still pictures as a portrayal of smooth motion. This phenomenon is the basis of both motion picture and television systems.

The important point, in the present discussion, is that the eye recognizes a slow change in light intensity. The period of the change may be a fraction of a second or it may be a minute, an hour, or a half-day in length. A television system must be capable of conveying these slow changes, no matter how long the period, to the receiver. The rapid scanning of the image of the scene in the camera produces a signal containing these slow changes as well as very rapid variations caused by the passage of the scanning beam over small light and dark areas of the image. The slow changes often have periods so long that they may be considered as d-c levels which simply change value occasionally. Hence, the signal is said to contain a d-c component. The television system must either pass the entire spectrum, including the d-c component, in each of its stages, or the signal must contain such information that it will be possible to restore the d-c component, which would be lost in an a-c-coupled system, when it finally arrives at the reproducer. Because of the well-known difficulties in constructing multistage d-c coupled amplifiers, it is desirable to use an a-c coupled system. It is fortunate that relatively simple means are known for d-c restoration, thus making possible the use of an a-c coupled system.

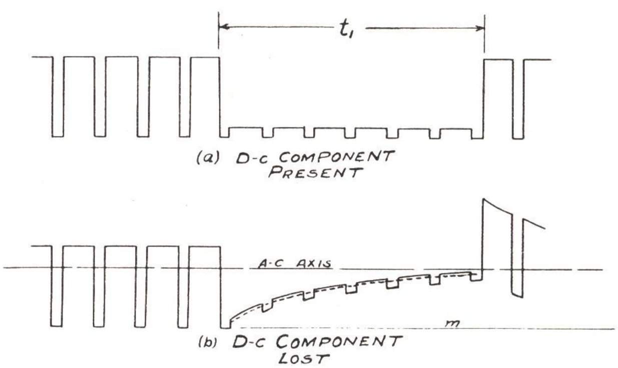

Figure 3-6 - D-C Component

Figure 3-6(a) illustrates a signal which contains a d-c component in the form of a temporary change in the amplitude of the pulses. The period t_1 embracing the low-amplitude pulses may be of any arbitrary length. The original signal is characterized by the constant level of the negative peaks of all the pulses, regardless of amplitude. After passing through an a-c coupled system (in which the time constants of the coupling networks are short compared to the period t_1), the signal becomes distorted approximately as shown in Figure 3-6(b). Here the negative pulse peaks no longer fall on a constant level, but the signal tends to adjust itself in a consistent manner about an axis called an a-c axis.

The a-c axis of a wave is a straight line through the wave, positioned so that the area enclosed by the wave above the axis is equal to the area enclosed by the wave below the axis. The broken line marked a-c axis in Figure 3-6(b) is actually the correct axis only for a wave composed of large pulses like the first four at the left. During the transient condition following the first short pulse, the line shown is not the true a-c axis, but represents the operating point of the amplifier in the a-c coupled system. The actual a-c axis of the short pulses (shown by the dotted line) gradually adjusts itself to coincide with the operating point of the amplifier. This adjustment is shown by the exponential rise of the signal during the interval t_1, but it is interrupted before completion by the resumption of the large pulses. Thence a second transient condition takes place, leading to a gradual restoration of the signal to its original form.

The departure of the pulse peaks from the original constant level indicated by the line m, is called *loss of the d-c component* or loss of "lows". It is interesting to note that this loss causes an increase in the peak-to-peak amplitude of the signal, a condition which is undesirable, especially in high-level amplifiers.

BLACK LEVEL

An absolute system of measurement must have a fixed standard reference unit or level. This rule applies to the problem of reproducing absolute light intensities. The simplest and most obvious reference for such a system is zero light, or *black level* as it is often called. This is a reference level which can be reproduced arbitrarily at any point in the system. Now if the television signal can be synthesized in such a way that frequent short intervals have some fixed relationship to actual black in the scene, then it becomes possible to restore the d-c component by forcibly drawing the signal to a fixed arbitrary level during these intervals.

D-C INSERTION AND D-C RESTORATION

Because the blanking or retrace periods are not useful for transmitting actual picture information, they offer convenient intervals for performing special control functions such as d-c restoration as mentioned in the previous paragraph. If the peaks of the blanking pulses are coincident with black level, or differ from black level by a constant amount, then d-c restoration can be accomplished simply by restoring these peaks to an arbitrary reference level. Thus, in Figure 3-6(b), if the peak of each pulse can be restored to the line m, then the signal will appear as in (a) and the d-c component will have been restored. Small errors will remain, corresponding to the displacements in level between pulses, but these are usually negligible and in any case do not become cumulative. Hence the restoration is essentially complete.

It now becomes apparent that an extremely important step in the synthesis of the television signal is that of making the peaks of the added blanking pulses bear some fixed relationship to actual black level in the scene. It was pointed out previously that the peaks of these pulses are produced by clipping off unwanted portions of the signal, as illustrated in Figure 3-4, C and D. A second, and most important, function is performed when the clipping is controlled in such a way that the resultant peaks have the required fixed relationship to black level. This process of relating the blanking peaks to actual black level is called *d-c insertion*, or insertion of the d-c component. A subsequent process, later in the system, of bringing these peaks back to an arbitrary reference level is called *d-c restoration*. D-C restoration must be accomplished at the input of the final reproducing device (the kinescope) in order to reproduce the scene faithfully.

It is desirable to restore the d-c component at other points in the system also, because the process reduces the peak-to-peak excursions of the signal to a minimum by removing increases in amplitude caused by loss of the d-c component. In a similar way, it is possible to remove switching surges, hum, and other spurious signal components which have been introduced by pure addition to the signal. Maintaining minimum excursion of the signal is important, especially at high-level points in the system, in order to avoid saturation in amplifiers and consequent distortion of the half-tones in the scene. For a specific example, d-c restoration helps to maintain constant sync amplitude in high-level amplifiers. In other words, it makes possible economies in the power capabilities of amplifiers such as the final stage in the picture transmitter.

Diagram 3 in Figure 3-5 illustrates part of a typical picture signal including two horizontal blanking pulses. It may be seen that there is a distinct difference between actual black level and blanking level which is prescribed as 5% of maximum blanking pulse amplitude. This difference is usually called *setup* and its magnitude was set as a reasonable compromise between loss of signal amplitude range and the need for a tolerance in operating adjustment. Setup is desirable as an operating tolerance in the initial manual adjustment of the clipper in that part of the system where the d-c is *inserted*. It simply insures that no black peaks in the actual picture signal are clipped off.

The accuracy with which setup is maintained depends on characteristics of the pickup or camera tube. Some types of pickup tubes produce signals during blanked retrace periods which are the same as, or are constantly related to, black level. In systems where such tubes are used, the magnitude of setup may be held constant automatically at whatever value is determined in the initial manual adjustment of the clipper circuit. In general, pickup tubes employing low-velocity scanning, such as the image orthicon, provide this kind of basic black level information. The iconoscope differs from orthicons in this respect, because the secondary emission resulting from the high-velocity scanning produces a potential distribution on the mosaic in which black level is far from the level existing during the retrace periods when the beam is cut off. In fact, the difference between black level and blanking level varies continuously as the scene brightness changes, because the potential distribution caused by resettling of the secondaries likewise changes. Automatic maintenance of setup, or pedestal height, cannot therefore be obtained by reference to the signal during blanked retrace periods in the iconoscope, but may be obtained by reference to actual black peaks in the picture signal. Where such reference is not practical, a manual control may be readjusted from time to time to keep the setup at the required value.

SYNCHRONIZING

The horizontal and vertical scanning circuits in a receiver are two entirely independent systems, both of which require extremely accurate information to keep them in step with the corresponding scanning systems in the camera, where the signal originates. Because the duration of sync pulses may be rather short, these pulses may be added to the picture signal in such a way as to increase the overall amplitude of the final signal without increasing the average transmitted power level very much. Thus, simple amplitude discrimination can be used to separate the synchronizing information from the incoming composite signal in the receiver. It is, however, desirable that a second increase in amplitude should not be used to distinguish between horizontal and vertical sync. The reason for this is that a further increase in signal amplitude would make necessary an increase in the peak power rating of the transmitter or else would unnecessarily restrict the power available for the picture and horizontal sync portions of the signal.

A synchronizing system has therefore been chosen in which both vertical and horizontal pulses have the same amplitude, but different waveshapes. Frequency discrimination may then be used to separate them in the receiver. The shapes of these pulses and their relation to the blanking pulses are illustrated in detail in Figure 3-5. Figure 3-7 is a functional block diagram showing the steps necessary to "utilize" the sync signals.

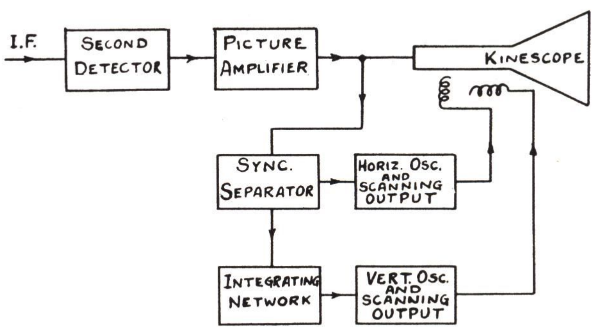

Figure 3-7 - Block Diagram of Picture-signal Amplifier and Scanning Circuits in Typical Receiver.

Diagrams 1 and 2 of Figure 3-5 illustrate a typical complete composite picture signal in the neighborhood of the vertical blanking pulse in each of two successive fields. Interlacing of the scanning lines is shown by the time displacement of the horizontal blanking pulses in one diagram with respect to those in the other diagram. This displacement is one-half of the interval of a scanning line ($H/2$).

All sync pulses appear below black level in an amplitude region which is sometimes called *blacker-than-black*; hence they can have no effect on the tonal gradation of the picture. Horizontal sync pulses are (except during the first portion of the vertical blanking interval) simple rectangular pulses, such as those appearing at the negative peaks or bases of the horizontal blanking pulses and during the last portion of the vertical blanking pulses. The duration of a horizontal sync pulse is considerably less than that of the blanking pulse, and the leading edge of the sync pulse is delayed with respect to the leading edge of blanking, forming a step in the composite pulse which is called the *front porch*. Correspondingly, the step formed by the difference between the trailing edges of sync and blanking is called the *back porch*. The purpose in forming the front porch is to insure that the horizontal retrace in the receiver (initiated by the sync pulse) does not start until after the blanking pulse has cut off the scanning beam. It also insures that any discrepancies which may exist in the leading edge of blanking do not effect either the timing or the amplitude of sync.

The choice of the nominal width of horizontal sync (0.08 *H*, see diagram 5 in Figure 3-5 was influenced by three factors. First, the width should be as great as possible so that the energy content of the pulses will be large compared to the worst type of noise pulses which may be encountered in the transmission process, thus providing maximum immunity to noise. Second, the width should not be greater than is necessary to meet the first condition, because average power requirements of the transmitter may thereby be minimized. Modulation of the picture transmitter is such that sync pulses represent maximum carrier power; hence it is desirable to keep the duty cycle as small as possible. Third, the horizontal sync pulses should be kept as narrow as possible so as to maintain a large difference between these pulses and the segments of the vertical sync pulses described in the following paragraph. Such a large difference makes it easier to separate the vertical sync from the composite sync signal. It has also been recognized that the back porch is useful for a special type of clamping for d-c restoration. Hence it should be as wide as possible.

Vertical sync pulses are also basically rectangular in shape, but are of much greater duration than the horizontal pulses, thus providing the necessary means for frequency discrimination to distinguish between them. However, each vertical sync pulse has six *slots* cut in it, which make it appear to be a series of six wide pulses at twice horizontal frequency, *i.e.*, wide compared to horizontal sync pulses. The slots contribute nothing to its value as a vertical sync pulse but do provide means for uninterrupted information to the horizontal scanning circuit.

Before and after each vertical pulse interval are groups of six narrow pulses called *equalizing pulses*. These also are for the purpose of maintaining continuous horizontal sync information throughout the vertical sync and blanking interval. The repetition frequency of the equalizing pulses and the slots in the vertical pulses is twice the frequency of the horizontal sync pulses. This doubling of the frequency does two things. First, it provides an arrangement in which the choice of the proper alternate pulses makes available some kind of a horizontal sync pulse at the end of each scanning line in either even or odd fields. Second, it makes the vertical sync interval and both equalizing pulse intervals exactly alike in both even and odd fields. The importance of this latter result will become evident in following paragraphs. It is important to point out that the leading edge (downward stroke) of each horizontal sync pulse and of each equalizing pulse, and the trailing edge (again the downward stroke) of each slot in the vertical pulses are responsible for triggering the horizontal scanning circuit in the receiver; hence the intervals of *H* or *H*/2 apply to these edges.

Perhaps the most difficult problem in synchronizing, and the one in which there is the largest number of failures, is that of maintaining accurate interlacing. Discrepancies in either timing or amplitude of the vertical scanning of alternate fields will cause displacement, in space, of the interlaced fields. The result is non-uniform spacing of the scanning lines, which reduces the vertical resolution and makes the line structure of the picture visible at normal viewing distance. The effect is usually called *pairing*. The maximum allowable error in line spacing in the kinescope, to avoid the appearance of pairing, is probably 10% or less. This means that the allowable error in timing of the vertical scanning is less than one part in 5000. This small tolerance explains why so much emphasis is placed on the accuracy of vertical synchronizing.

The presence of a very minute 30-cycle component in the *vertical* scanning invariably causes pairing. The fact that the rasters produced in alternate fields are displaced with respect to each other by half a line means that the *horizontal* sync signal has an inherent 30-cycle component. It is this situation, and the need to prevent any transfer of the 30-cycle component into the vertical deflection, which account for the introduction of the double-frequency equalizing pulses before and after the vertical sync pulses. The vertical sync pulses are separated from the composite sync signal, before being applied to the vertical scanning oscillator, by suppressing the horizontal sync pulses in an integrating network similar to that illustrated in Figure 3-8.

Most receivers employ integrating networks of three stages instead of the two illustrated.

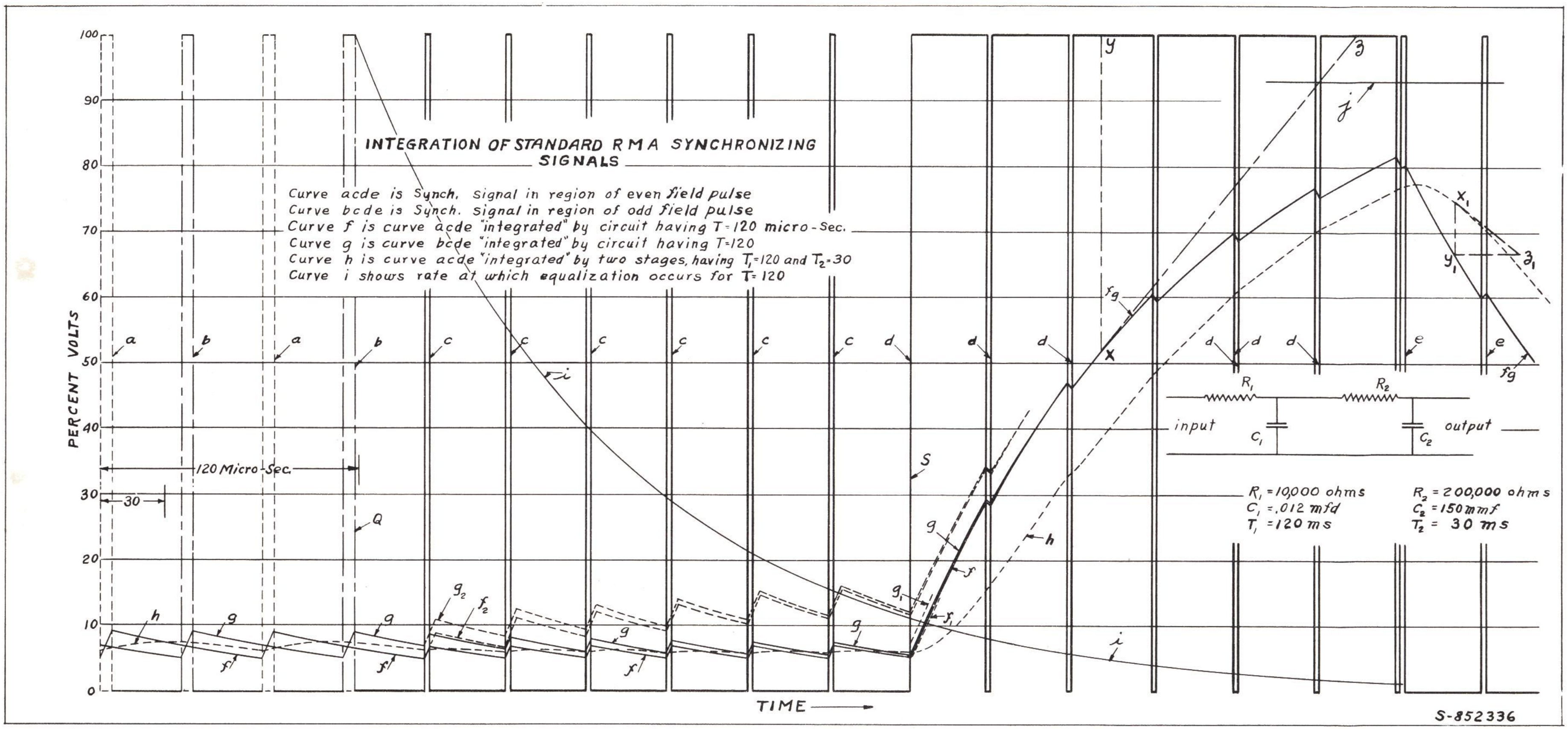

Figure 3-8 - Integration of RMA Synchronizing Signals however, the general character of the circuit action is clearly shown by the wave-form diagrams* in Figure 3-8. In simple terms, the equalizing pulses before the vertical sync pulses cause the integrating network to "forget" the difference between alternate fields by the time the vertical sync pulses begin. This is illustrated by the gradual convergence of curves f and g during the equalizing pulse interval, as the result of integration in the first stage alone. The effect of further integration in the second stage is shown by curve h, which is typical of the pulses applied to the vertical oscillator in a receiver. Thus, the 30-cycle component is effectively eliminated, from the standpoint of accurate timing of the start of vertical retrace, by the addition of the first set of equalizing pulses and the slots in the vertical pulse itself. The second set of equalizing pulses which follow the vertical pulse affect to some extent the impedance of the circuit to which the vertical scanning oscillator is coupled, and thus affect the amplitude of its output; hence these pulses help to provide more nearly constant output of the oscillator. Both sets of equalizing pulses contribute materially to the necessary accuracy of vertical synchronizing.

The width of an equalizing pulse is half the width of a horizontal sync pulse (see diagram 4 of Figure 3-5, and Figure 3-8). This width is chosen so that the a-c axis of the sync signal does not change at the transition from the line-frequency horizontal sync pulses to the double-frequency equalizing pulses. The curves f_2 and g_2 in Figure 3-8 illustrate the undesirable effect of making the equalizing pulses the same width as the horizontal sync pulses. There is a slight rise in the integrated wave during the equalizing pulse interval, which could cause premature triggering of the vertical oscillator in the receiver if the hold control were adjusted near one end of its range. This rise in the integrated wave results from the change in the a-c axis.

The width of the slots in the vertical sync pulses is approximately equal to the width of the horizontal sync pulses. The slots are made as wide as possible so that noise pulses or other discrepancies occurring just prior to the leading edge of a slot (*i.e.*, near the end of the preceding segment of a vertical pulse) do not trigger the horizontal oscillator. Premature triggering can happen if the noise pulse is high enough and if it occurs very close in time to the normal triggering time. Increased time-separation (a wider slot) reduces likelihood of such premature action. Here again, the requirements of special clamping also are met more easily if the slots are made as wide as possible.

A further important advantage of the RMA system of separating the vertical sync by frequency discrimination is that the integrating network is a potent factor in reducing the effect of noise on vertical synchronizing. Noise signals contain mostly high-frequency components; hence they are almost completely suppressed by the integrating circuit.

Differentiation, or suppression of the low-frequency components, of the sync signal before it is applied to the horizontal scanning oscillator is done sometimes, but it is not necessary, and has not been indicated in Figure 3-7.

The methods just described for synchronizing the scanning circuits in a television receiver are complicated by the need for transmitting the complete information over a single channel. In the case of the scanning circuits in the cameras, however, the situation is very different. The cameras and the synchronizing generator are so close to each other that there is no problem in providing as many wire circuits as may be desired. Therefore it is customary to use what are called *driven* scanning circuits in cameras and sometimes in picture monitors used with the cameras. Separate pulse signals, called *driving signals*, are produced in the synchronizing generator for exclusive use in the terminal equipment. Horizontal and vertical driving signals are completely independent of each other in the RCA system and are carried on separate transmission lines to the points of application. The driving signal pulses trigger directly the sawtooth generators which produce the scanning wave forms. This method reduces interlacing errors in the terminal equipment to the errors inherent in the driving signals.

Figure 3-9 illustrates a portion of the scanning lines appearing on a kinescope as a result of the application of a television signal composed of RMA sync and blanking pulses. The group of lines shown are those occurring in the neighborhood of the vertical retrace period including a few before and a few after the vertical blanking pulse. As noted on the diagram, the triggering of the lines has been displaced both vertically and horizontally so that the shadows produced by the sync and blanking pulses appear near the center of the raster rather than

* *Diagram prepared by A. V. Bedford, RCA Laboratories, for presentation to the N.T.S.C.*

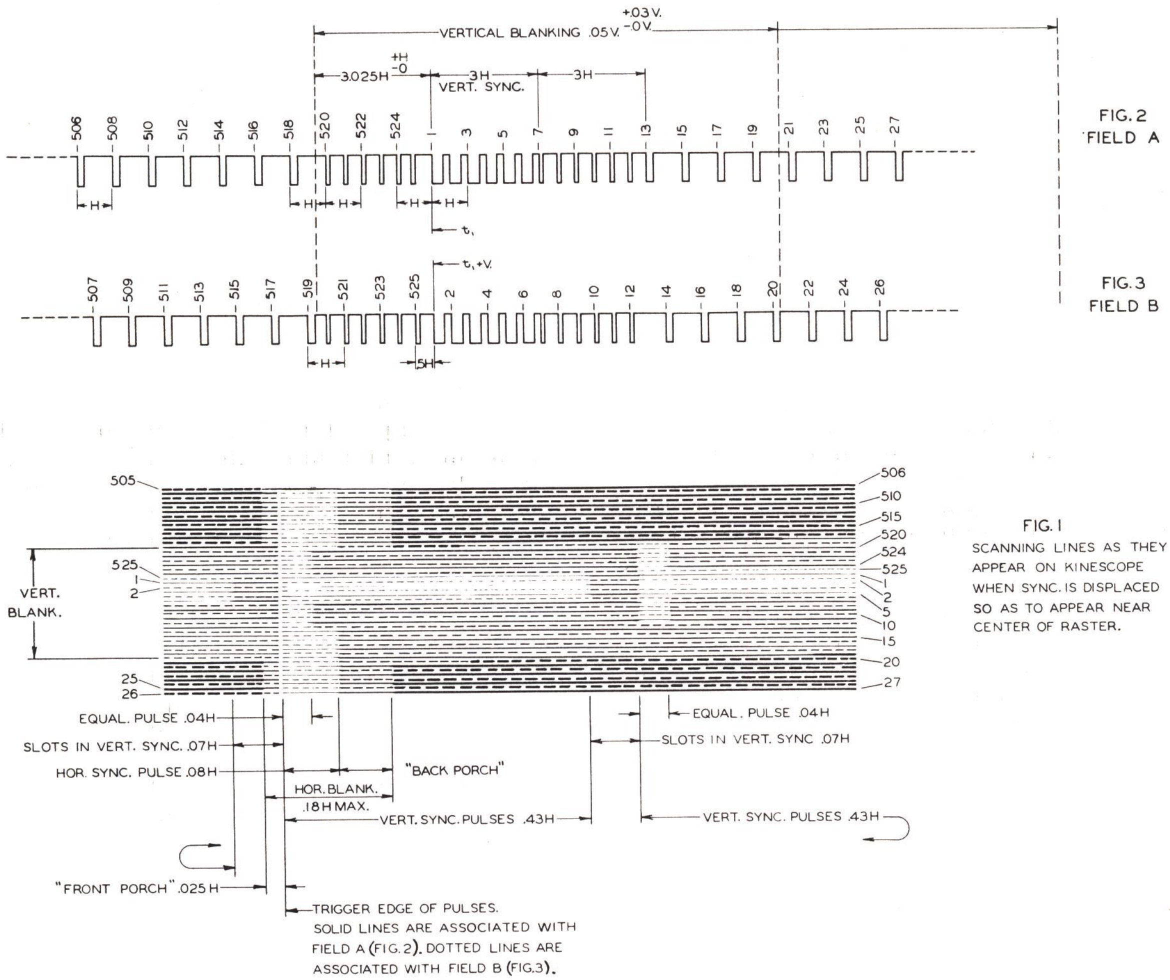

Figure 3-9 - Television Synchronizing Signal and Pulse Cross

in the normal positions at the edges of the raster. This displacement is brought about simply to clarify the illustration of the effect of the pulses on the raster.

The shadows produced thus are called a *pulse cross*. When expanded vertically so that individual scanning lines become easily apparent, the pulse cross becomes a ready means of checking the performance of the sync generator. The shadows produced by each different kind of pulses are indicated clearly on the diagram. With linear scanning, the horizontal dimensions of the shadows are measures of time or pulse width, and, because of the expanded scale, they provide a relatively accurate means of measuring pulse width. Furthermore, by counting appropriate lines, the numbers of equalizing pulses, slots, vertical sync pulses, etc. can be checked easily.

A useful piece of station test equipment can be made by modifying the deflection circuits in a picture monitor to provide the displacement of the lines and the extra large vertical expansion described.

AUTOMATIC FREQUENCY CONTROL OF SCANNING

The constant search for means of immunization against the effects of noise has brought about the development of automatic frequency control (afc) of the scanning circuits in television receivers. In triggered circuits, each scanning line (and each field) is initiated individually by a pulse in the incoming signal. In contrast to this, in an afc system, scanning generators are governed by stable oscillators which, in turn, are controlled by voltages obtained from phase comparison of the incoming sync pulses with the scanning signals themselves. The time-constant of the comparison circuit is usually made long, compared to the period of the scanning, so that random noise pulses have very little effect on the resulting control voltage, and correspondingly little effect on the scanning frequency. The fact that such afc circuits are keyed provides a further immunization factor by eliminating the possible effect of all noise pulses except those which coincide with the short keying intervals. The use of afc scanning circuits makes possible accurate synchronizing of a receiver under such bad conditions of noise that the masking of the picture by the noise renders it completely unusuable. Thus, failure to synchronize may be largely eliminated as a limiting factor in picture reception.

AFC may be used with both vertical and horizontal scanning circuits, but so far is being used commercially for horizontal circuits only. One reason for not using afc with the vertical circuits is that the time-constant must be very long to provide a stable control voltage. As a result, the circuit will not recover from an extended interruption of the incoming signal until an intolerably long time has elapsed. The frequency of the oscillator drifts during an interruption, and may not recover for a large number of seconds after the signal returns. During the period of recovery, the raster rolls over continuously at a decreasing rate until control is restored. The time-constant of the horizontal circuit, on the other hand, may be short enough so that recovery takes place in less than one field. Triggered scanning circuits, of course, recover from signal interruptions very rapidly, but they do not have the same high immunity to noise that the afc circuits have.

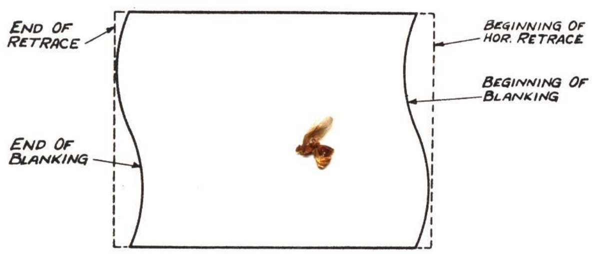

Figure 3-10 - Effect of Frequency Modulation of Horizontal Sync and Blanking on Shape of Raster in Receiver with AFC of Horizontal Scanning.

As a result of the use of afc circuits in receivers, a high degree of frequency stability is required in the horizontal sync and blanking signals. Frequency modulation of the horizontal pulses is intolerable because it causes the right- and left-hand edges of the blanked raster in the receiver, as well as vertical lines in the scene, to assume the same shape as the modulating wave. As shown in Figure 3-10, the border of the complete raster in the receiver is rectangular, but frequency modulation of the horizontal sync and blanking will distort the shape of the border produced by blanking. Frequency modulation by a 60-cycle sine wave is illustrated.

Horizontal retrace begins along a straight vertical line regardless of timing; and since this retrace is controlled by a stable oscillator in the receiver which is not responsible to short-time changes in sync timing, the presence of variations in sync timing and of corresponding changes in blanking pulse timing, will show as a displacement of the edges of the blanked raster. The frequency stability of the sync generator must therefore be at least equal to the stability of the oscillators used in afc receivers. The maximum rate of change of frequency allowable in a sync generator has been specified by RMA as 0.15% per second. This is a rather strict tolerance, as indicated by the fact that it allows a total displacement of only 1/32 of an inch (approx.) in a period of one field in a picture 10 inches wide.

FILM PROJECTION

The use of standard sound motion picture film for television program material offers a special problem which arises from the difference in the picture repetition rates use. For reasons explained previously, the rate used for television is 30 frames and 60 fields per second. The standard speed for sound film, both 16mm and 35mm, is 24 frames per second, and since each frame is projected twice, the picture rate is 48 per second. The basic problem of reconciling the frequency difference has been met by using special projectors for television, in which alternate frames of the film are projected twice and the remainder are projected three times. In this way, 60 pictures are obtained in place of the usual 48, but the average speed of the film through the projector is unchanged; hence the sound take-off is entirely normal.

Another problem also presents itself in the use of intermittent film projectors for television. The vertical scanning period occupies from 92% to 95% of the total period. If the projected image is to be thrown on the pickup tube during the scanning period at all, it must be for the entire time so that all parts of the area will be subject to the same lighting conditions. Such an arrangement would leave only the vertical retrace period (5% to 8% of the total, or approximately one thousandth of a second) in which to pull down the film to the next frame. 35mm film will not stand up under accelerations produced by sprocket-hole pull-down in such a short period; hence some other scheme must be used. The method which has been adopted for use with intermittent projectors makes use of the storage property of certain kinds of pickup tubes, such as the iconoscope. The frame of film is projected with very intense illumination during the vertical blanking period only, while neither the pickup tube nor the receiver is being scanned. Then the light is cut off and the pickup tube is scanned in the absence of any optical image from the film. The signal generated during this scan results from charges stored on the sensitive surface during the preceding flash of light. While the light is cut off during the scan there is ample time to pull the film down before the next flash of light, without exerting destructive forces. The pulses of light may be obtained by chopping the output of a continuous source with a rotating disk, or (with a special type of arc lamp) by pulsing the source itself by electronic means. The storage properties of pickup tubes for this purpose must be sufficiently good so that dissipation of the stored charges is negligible between light pulses. Appreciable dissipation causes loss of contrast at the bottom of the picture.

Another solution to the problem of film projection in television is the use of a continuous projector, a type which produces a stationary image from continuously moving film by means of moving mirrors or lenses. This solution has not been accepted commercially so far because of practical difficulty in making the optical system sufficiently accurate to stop motion of the image completely.

The film problem in England, Europe, and other areas where 50-cycle power systems are standard, and where the television field frequency is also 50 cycles per second, is simpler in one respect, namely that it is not necessary to use the two-three ratio for projection of alternate frames of film. Instead, the film is projected as it is in theaters where each frame is projected twice. No attempt is made to compensate for the difference between the 24 frame taking speed and the 25 frame projection speed. The results are an approximate 4% increase in the apparent speed of motion of objects in the scene (which is probably negligible) and a slight rise in the pitch of all sounds. This latter effect is the more objectionable of the two, though generally it is not noticeable in speech and many other ordinary sounds. The change in pitch is undoubtedly noticeable to the trained musician in the case of musical sounds and must produce an unpleasant mental reaction to the music. However, no easy solution to the problem is known, and the situation is accepted without serious complaint. The other aspects of the film problem are not affected by the use of 50 fields instead of 60.

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The preceding discussion is necessarily brief and cannot serve as much more than an outline for further reading. There are many papers dealing more comprehensively with the details and problems associated with the various parts of the television system. References to some of these are included in the following bibliography. Most of the papers referred to also include references to others which, *in toto,* comprise a comprehensive list.

One book deserves special mention as a reference covering much of the engineering background of our television system. It is entitled, "Television Standards and Practice," (McGraw-Hill Book Co., 1943), and is essentially an abridged version of the proceedings of the National Television System Committee, as edited by Donald G. Fink. It includes a statement of the standards recommended by the Committee to the Federal Communications Commission, discussion of the investigations on which the recommendations were based, and references to pertinent papers.

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PART II

FUNDAMENTAL CIRCUITS

INTRODUCTION

The foregoing discussion of basic concepts shows that television circuits use vacuum tubes and components in ways that differ significantly from audio- or radio-frequency circuit applications. Sinusoidal wave forms are the exception rather than the rule. Usually the complex wave forms observed in television circuits are rectangular pulses, sawtooth shapes, or combinations of both. Vacuum-tube grids may be driven from a point well below cut-off potential into the positive region where grid current flows. The vacuum tube may operate as a switch in which total voltage and current values are used rather than small incremental quantities. Also time becomes an important factor since certain circuits must function in a particular manner with respect to time. The following notes are concerned with some fundamental television circuits employing concepts outlined above.

OVERDRIVEN AMPLIFIER

An overdriven amplifier is one in which the grid voltage is varied from a point below the tube cut-off voltage to some value in the positive region where grid current flows. This type of amplifier may be used as a limiting or clipping device or as a pulse amplifier. A circuit diagram is shown in Figure 3-11.

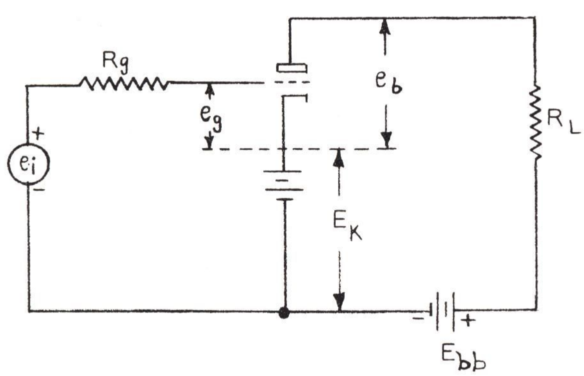

Figure 3-11 - Overdriven Amplifier

In the overdriven amplifier the following symbols apply:

$\overline{r}_p$ = d-c plate resistance = e_b/i_p. For $e_g = 0$ assume $\overline{r}_p$ constant

= 10,000 ohms approximately for 6SN7.

$\overline{r}_g$ = d-c grid resistance = e_g/i_g. Assume $\overline{r}_g$ constant for given tube

= 1,000 ohms approximately for 6SN7.

E_{co} = grid voltage for plate current cut-off

= E_{bb}/μ for triodes only.

R_g = grid limiting resistor which limits grid voltage to a value slightly positive with respect to the cathode.

Figure 3-12 shows an equivalent circuit and the resultant wave forms when a sinusoidal voltage e_i is applied to the grid. In this equivalent circuit, switches S_1 and S_2 are open when the grid voltage is below cut-off. They are closed when the grid voltage is positive with respect to the cathode.

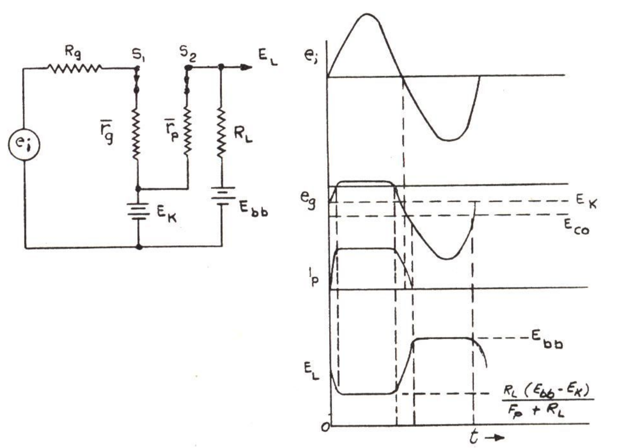

Figure 3-12 - Overdriven Amplifier, Equivalent Circuit and Wave Form.

When $e_i = 0$, the grid voltage e_g is equal to E_k. When $e_i - E_k = 0$, grid current flows and limits e_g to a slightly positive value. The grid voltage remains positive and constant, because of the drop across R_g (note that $R_g >> \overline{r}_g$), until e_i approaches the 180-degree point of the cycle. During the first half-cycle i_p rises rapidly to a value determined by $\overline{r}_p$, R_L, E_k, and E_{bb}, and then remains constant until e_g becomes negative. When $e_i + E_k$ is equal to the cut-off voltage, i_p falls to zero and no plate current flows for the remainder of the cycle. During the time that e_g is zero or slightly positive,

$$E_L = \frac{R_L\,(E_{bb} - E_k)}{\overline{r}_p + R_L}$$

When plate current is cut off (S_2 open),

$$E_L = E_{bb}.$$

In this circuit the sinusoidal input voltage has been clipped at both top and bottom to give a rough square-wave output voltage.

CATHODE FOLLOWER

A linear cathode-follower stage differs from the ordinary amplifier circuit in five ways: (1) the signal polarity is not inverted, (2) the gain is less than 1, (3) the output impedance is low, (4) the input impedance is high, and (5) the input capacitance is lowered. It may be used (1) after a pulse-shaping circuit to prevent loading of the circuit, (2) to drive tubes requiring grid power without altering the waveshape, or (3) as a device to match high to low impedances. It can deliver high currents to a low-impedance load without altering the waveshape. The basic circuit and equivalent circuit are shown in Figure 3-13 for incremental quantities.

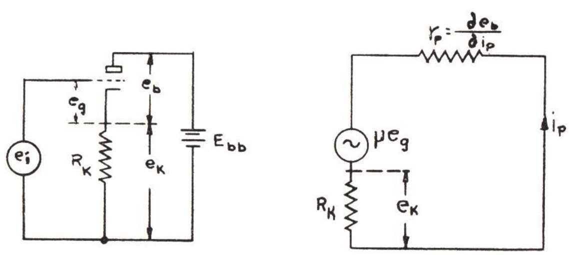

Figure 3-13 - Cathode Follower Circuit

From Figure 3-13 it may be seen that $e_g = e_i - e_k$; hence μe_g becomes $\mu(e_i - e_k)$. Then in the equivalent circuit

$$i_p = \frac{\mu(e_i - e_k)}{r_p + R_k}$$

and the output voltage e_o is

$$e_o = e_k = i_p R_k$$

$$= \frac{\mu(e_i - e_k)\,R_k}{r_p + R_k}$$

from which the gain A is expressed

$$A = \frac{e_k}{e_i} = \frac{\mu\,R_k}{r_p + (\mu + 1)\,R_k}$$

If the amplification factor μ is large, compared to 1, the gain A becomes

$$A = \frac{\mu\,R_k}{r_p + \mu\,R_k}$$

In another form, the gain may be expressed

$$A = \frac{\frac{\mu}{r_p}\,R_k.}{1 + \frac{\mu}{r_p}\,R_k}$$

$$= \frac{g_m\,R_k}{1 + g_m\,R_k}$$

The last equation resembles the equation for the gain of an ordinary amplifier stage reduced by the factor $\frac{1}{1 + g_m R_k}$ The grid-to-cathode input capacity is reduced by the same factor, and the total input capacity becomes

$$C_i = C_{gp} + \frac{C_{gk}}{1 + g_m\,R_k}$$

Similarly, the output impedance is reduced to

$$Z_o = \frac{R_k}{1 + g_m R_k}$$

MULTIVIBRATORS

A multivibrator is a circuit arrangement in which two tubes operate as switching elements to control the duration of current flow in the two load resistances. It may be compared to an oscillator, in that its action can be self-sustained. Such a multivibrator is called a "free-running" multivibrator. It may be synchronized to a desired frequency by either a sine wave of the given frequency or by a pulse whose repetition rate is equal to the desired frequency. There is also a type of multivibrator known as a "flip-flop", "one-kick", or "one-shot" multivibrator. This type of multivibrator performs one cycle of operation only when triggered by an external synchronizing signal.

Figure 3-14 is a circuit diagram of an unbiased free-running multivibrator. Capacitor

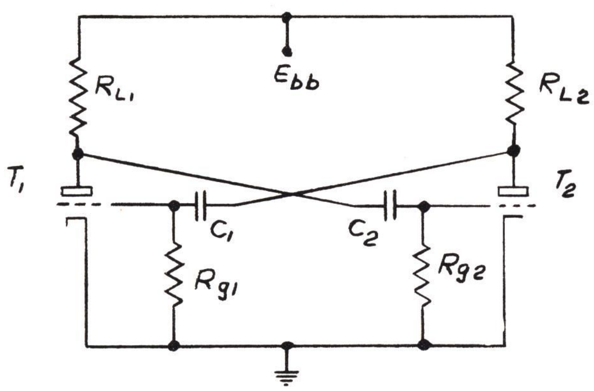

Figure 3-14 - Unbiased Free-running Multivibrator

C_1 couples the grid of T_1 to the plate of T_2. Similarly, C_2 couples the grid of T_2 to the plate of T_1. The circuit operates as follows: Suppose E_{bb} is applied when both tubes tend to conduct. Any small difference in circuit values or tube characteristics will result in one tube carrying more current than the other. Suppose more current flows in T_1. The greater voltage drop in R_{L1} is impressed on the grid of T_2, making that grid more negative and decreasing the current flow in T_2. The plate potential of T_2 rises, and this drives the grid of T_1 toward positive potential, causing T_1 to draw a still greater current. The effect is cumulative and results in T_1 carrying maximum current while T_2 is cut off.

The cycle of operation following the cut-off of T_2 is shown in Figure 3-15. The plate vol-

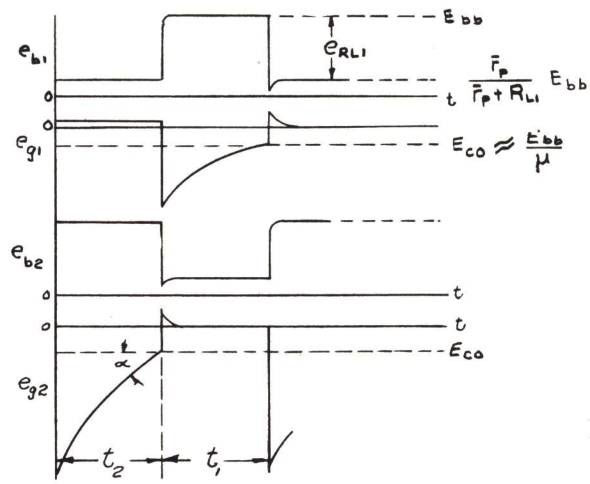

Figure 3-15 - Operating Cycle of Free-running Multivibrator

tage of T_1 drops to a value equal to $\frac{\bar{r}_p}{\bar{r}_p + R_{L1}} E_{bb}$. Since the grid of T_2 is coupled to the plate of T_1 through C_2, the grid voltage of T_2 also drops below zero by an amount equal to e_{RL1}. Grid voltage e_g tends to go positive because e_{b2} rises to E_{bb} when T_2 is cut off; however, C_1 charges quickly through R_{L2} and r_{g1} and leaves e_{g1} at approximately zero potential. Capacitor C_2 begins to discharge exponentially through R_{g2} and R_{L1} and $\bar{r}_{p1}$ in parallel. The equivalent circuit, for C_2 discharging, is shown in Figure 3-16.

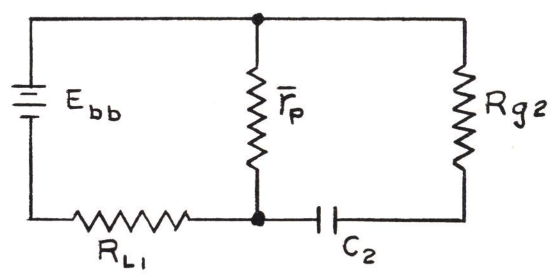

Figure 3-16 - Capacitor Discharge Circuit

The equation for the discharge of a capacitor is

$$e_c = E_o \epsilon^{-t/RC}$$

where
e_c = voltage on capacitor at time t
E_o = total discharge voltage
RC = time constant of discharge circuit.

Since we are interested primarily in e_{g2}, we shall consider the voltage across R_{g2}. At the beginning of the discharge $e_{g2} = e_{RL1}$. The steady-state condition toward which e_{g2} is tending is zero volt; however, when e_{g2} reaches cut-off voltage, tube T_2 will begin to conduct, and tube T_1 will be cut off.

From Figure 3-10 it can be seen that the total resistance in the discharge path is

$$R_{g2} + \frac{\bar{r}_{p1} R_{L1}}{\bar{r}_{p1} + R_{L1}}$$

Stray capacity is neglected in the calculations, but tends to round the corners of the plate-voltage wave form as shown in Figure 3-15. From the foregoing we may write the equation for the voltage on the grid of T_2:

$$e_{g2} = e_{R_{L1}} \epsilon^{-t/RC}$$

$$E_{CO} = e_{R_{L1}} \epsilon^{-t_2/\left(R_{g2} + \frac{\bar{r}_{p1} R_{L1}}{\bar{r}_{p1} + R_{L1}}\right) C_2}$$

(specific equation to point of cut-off).

In the usual design problem all the constants are known or can be determined, with the exception of R_{g2} and C_2. The value of R_{L1} is determined by the amplitude of plate-voltage change desired. E_{CO} and $\bar{r}_{p1}$ depend upon the tube type. The time interval t_2 is known for a particular application and is the time that T_2 is not conducting. The product $R_{g2}C_2$ may be calculated from the equation for voltage across R_{g2}.

The operation of T_1 follows an identical cycle when it is cut off. The sum $t_1 + t_2$ of the cut-off periods determines the total period of the cycle. The frequency of the multivibrator may be varied by varying either or both grid resistors.

It will be noted in Figure 3-15 that e_g approaches E_{CO} at the angle α. Since this angle is small, any variation in tube characteristics or components causing a shift in E_{CO} will alter the cut-off period t because the point of intersection of e_g with E_{CO} will change. When it is essential that t remain nearly constant over a long period of operation, the grid may be returned to E_{bb} as shown in Figure 3-17.

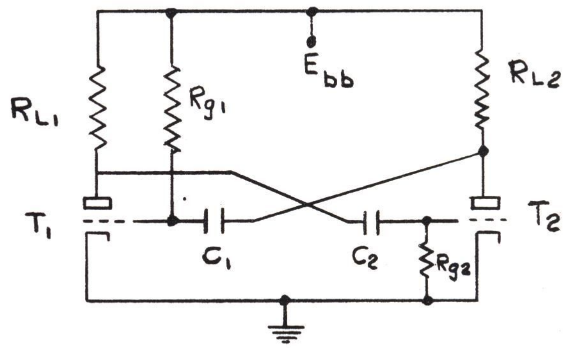

Figure 3-17 - Grid Return Circuit

The discharge wave form for e_{g1} is shown in Figure 3-18. In this example, e_{g1} is heading for E_{bb} instead of zero potential as in the previous case, and the angle α is large. Small

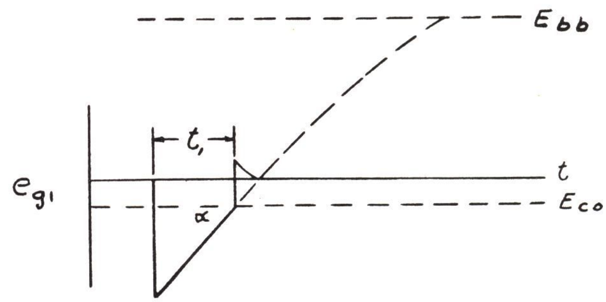

Figure 3-18 - Grid Voltage Wave Form

variations in E_{CO} will not greatly alter the intersection of e_{g1} and E_{CO}, and thus t_1 will remain very nearly constant. The equation for the discharge of C_1 becomes

$$E_{bb} + E_{CO} = (e_{R_{L2}} + E_{bb})\, \epsilon^{-t_1/RC}$$

An example of the so-called "flip-flop" multivibrator is shown in Figure 3-19 with the associated wave forms. Tube T_2 is normally conducting, and plate-current flow through R_k keeps T_1 cut off. When the grid of T_1 receives the trigger pulse, e_{p1} decreases and drives the grid of T_2 below cut off. T_2 remains cut off until C_2 discharges to the cut-off potential, at which

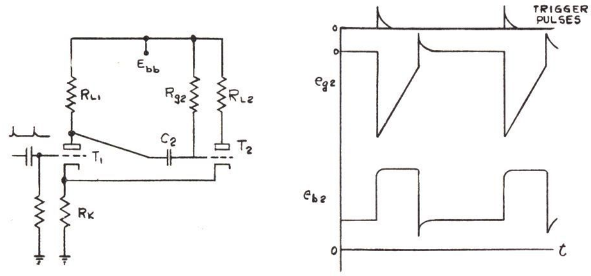

Figure 3-19 - "Flip-flop" Multivibrator

point T_2 resumes conduction until another trigger pulse is received.

CATHODE-COUPLED MULTIVIBRATORS

The multivibrators discussed thus far operate well up to pulse repetition rates of several thousand pulses per second. At higher repetition rates, stray capacity tends to cause unstable operation. To minimize stray-capacity effects and extend the stable range of operation, one can resort to cathode coupling between stages.

A cathode-coupled multivibrator is shown schematically in Figure 3-20.

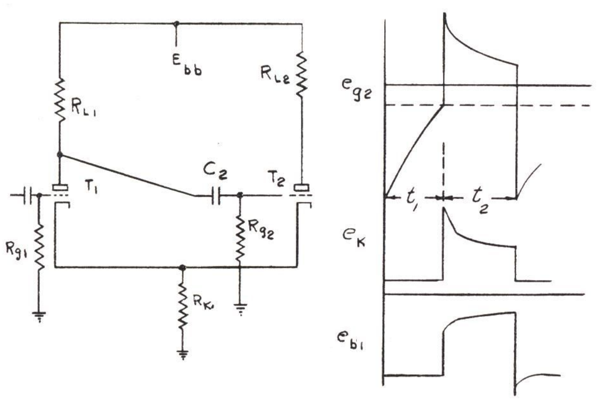

Figure 3-20 - Cathode-coupled Multivibrator

When $+B$ voltage is applied to the circuit, plate-current flow establishes across R_k a bias voltage common to both tubes. At the same time the voltage drop across R_{L1} is impressed on the grid of T_2, reducing the plate current in T_2 and lowering the bias voltage across R_k. With lower bias voltage, T_1 carries a larger plate current, and the resulting plate-voltage drop drives the grid of T_2 more negative. The process is cumulative and rapid, so that T_2 is cut off quickly.

Capacitor C_2 discharges in normal manner until the grid reaches cut-off potential. This cycle is shown, during t_1, in Figure 3-20. Then T_2 begins to conduct. The flow of T_2 plate current through R_k reduces the plate current in T_1 because of increased bias. The plate voltage of T_1 rises as the plate current decreases, and this voltage rise is coupled to the grid of T_2 through C_2. The grid of T_2 is driven positive by this cumulative process. Heavy current in T_2 cuts off T_1.

Now C_2 begins to charge through R_{L1} and the parallel combination of $\overline{r}_g$ and R_{g2}. It charges quickly until the grid voltage is reduced to cathode potential. Then T_2 grid current ceases, and C_2 continues to charge through R_{L1} and R_{g2}. At the end of the time interval t_2 plate current in T_2 has been reduced sufficiently to allow T_1 conduction. From this point on, the cycle is repeated.

This type of multivibrator is inherently unstable because neither tube can keep the other in cut-off condition. Also, the effect of stray capacity is reduced by interstage coupling to one grid only, and the input capacity of that grid is reduced by cathode-follower action. The controlling signal is coupled between stages by a low-impedance circuit in the cathodes, in which the effect of stray capacity is lessened. A multivibrator of this type may be operated in reliable manner at a pulse repetition rate of a million pulses per second.

CLIPPING CIRCUITS

Clipping circuits are used to eliminate undesired portions of complex wave forms by limiting the amplitude excursion in either the positive or negative direction, or in both directions. Clippers or limiters are usually applied in circuits in which pulses are formed and shaped to desired specifications.

Figure 3-21 illustrates a simple peak-clipping circuit which may be used to form a square

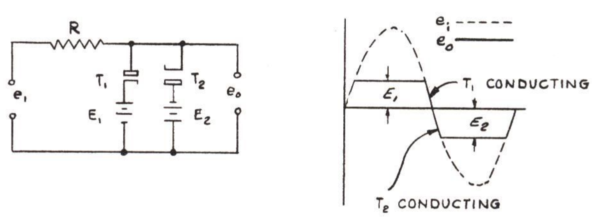

Figure 3-21 - Peak Clipping Circuit

wave from a sinusoid. Two diode elements, T_1 and T_2, are connected as shown. Bias battery E_1 keeps tube T_1 cut off until input voltage e_i increases in the positive direction to a value equal to E_1. Further increase in e_i causes conduction of T_1 and results in a voltage drop across R. As e_i increases, both the current in T_1 and the voltage drop across R increase so that the output voltage e_o is fairly constant after e_i becomes slightly greater than E_1. A similar condition holds for the negative half-cycle of the input voltage. In this, the output voltage increases in the negative direction until bias E_2 is overcome. Then conduction in T_2 limits the output voltage to a fairly constant value. Wave forms for the cycle of operation are shown in Figure 3-21.

To produce, from a sine wave, a square wave with a short rise time by using a clipper of this type, it is necessary to connect several stages in cascade, inserting amplifiers between stages.

The overdriven amplifier discussed on previous pages may also be used for performing a clipping operation. Figure 3-22 is a practical

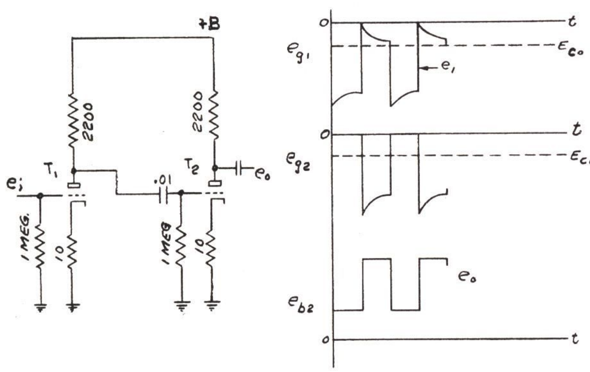

Figure 3-22 - Triode Clipper Circuit

triode clipper circuit utilizing a type 6SL7 tube. It may be desirable, for example, to remove overshoots or distortion in the tops of a square wave such as e_i in Figure 3-22. If e_i is symmetrical about the a-c axis, the grid of T_1 will assume a bias voltage, due to grid current, which will permit just the tip of the pulse to reach zero potential with respect to the cathode. If the pulse amplitude is sufficiently large, the negative excursions will drive the tube beyond cut off and eliminate the overshoot on the negative half-cycle.

The signal on the plate of T_1 consists of a square wave with overshoots eliminated in the positive half-cycle. By passing this signal through T_2, the overshoot is eliminated in the negative half-cycle, and a clean square wave is obtained in the output.

In the foregoing examples of clipping circuits, the action was symmetrical about the a-c axis. In some cases it may be desirable to clip only the tips of positive pulses, retain the tips, and eliminate the remainder of the wave form. Such a circuit and the appropriate wave forms are shown in Figure 3-23. Suppose the input voltage consists of alternate positive and

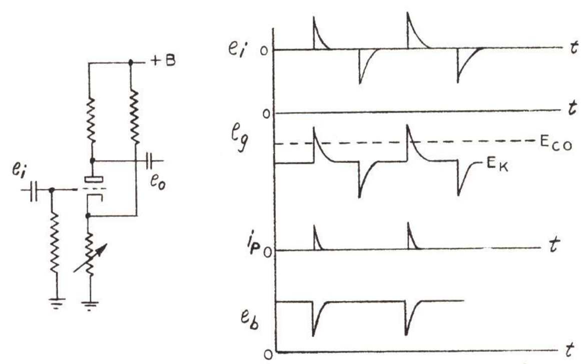

Figure 3-23 - Clipper Circuit

negative pulses obtained by differentiating a square wave. It is desired to clip the positive pulses midway between the axis and the tips. Voltage relationships are shown in Figure 3-23.

The clipping level is set by adjusting the bias in the cathode circuit so that, without signal, the tube is biased beyond cut-off. Only the positive tips of the input pulses cause plate current to flow.

In the clipping circuits described thus far, no attempt has been made to compensate for the inherent curvature near cut-off in the plate-current-cut-off type of clipper. Where the clipper is used to clip the blanking pulse and establish black level, as in Figure 3-4C, it is imperative that the slope of the grid characteristic curve remain constant to the clipping point; for this will prevent squashing of the video signal near black level and avoid change in the transfer characteristic. The linear clipper shown in Figure 3-24 accomplishes the desired result.

The linear clipper circuit includes a pentode V_1, a load resistor R_2 in series with a diode section V_2, and an additional load resistor R_1

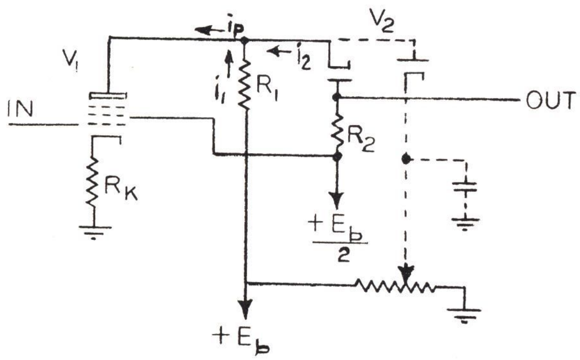

Figure 3-24 - Linear Clipper Circuit

in parallel with R_2 and V_2. The value of R_1 is approximately 20 to 30 times that of R_2. Both plate and screen supplies are regulated.

Figure 3-25 shows the characteristic curve for the linear clipper.

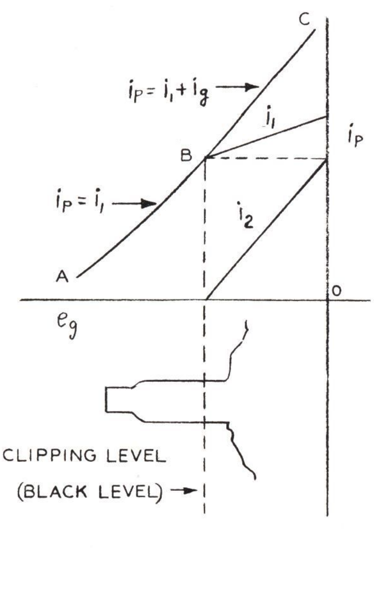

Figure 3-25 - Linear Clipper Characteristic

When V_1 is operating on the linear portion B-C, the plate current i_p is $i_1 + i_2$, and the plate voltage is less than $E_b/2$; hence V_2 conducts and causes signal current i_2 to flow in R_2. At point B the plate voltage of V_1 is equal to $E_b/2$. Between B and A the cathode voltage of V_2 is greater than $E_b/2$; therefore i_2 is zero, and there is no change in signal output voltage. Thus the blanking pulse is clipped at black level. Only the linear portion of the curve between B and C is used for the picture signal.

Cut-off in this clipper is abrupt. The use of a pentode tube permits an abrupt change in external load resistance without affecting plate current. As i_2 approaches zero, the ratio i_1/i_2 changes rapidly, resulting in a rapid change of V_2 cathode voltage in the cut-off region.

By adjusting the equivalent bias on V_1, point B can be made to coincide with black level.

A serious drawback of the linear clipper is capacity feed-through of transients. This trouble can be cured by connecting a second diode element, as shown by the dotted lines in Figure 3-24. By proper bias adjustment the second diode can be made to conduct at a potential just above cut-off of the limiter so that unwanted signals are shunted to ground when the limiter is inoperative.

BLOCKING OSCILLATORS

A blocking oscillator is a form of self-pulsed oscillator that is used as a simple means for obtaining a short pulse at some desired repetition rate. Figure 3-26 is a schematic diagram of a simplified blocking oscillator circuit. The coupling coefficient of the iron-core transformer T is very nearly unity. The connection polarities of the transformer must be as shown. Wave forms for the operating cycle are given in Figure 3-27.

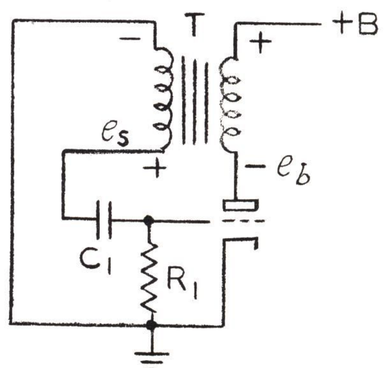

Figure 3-26 - Blocking Oscillator Circuit

When $B+$ is applied and plate current starts to flow, a voltage develops in the primary winding, due to the inductance drop $L\ di/dt$. This voltage is coupled to the secondary so as to cause the grid voltage to rise in the positive direction. Thus, the plate current is further increased. The effect is cumulative and causes the grid to go positive quickly. As the grid

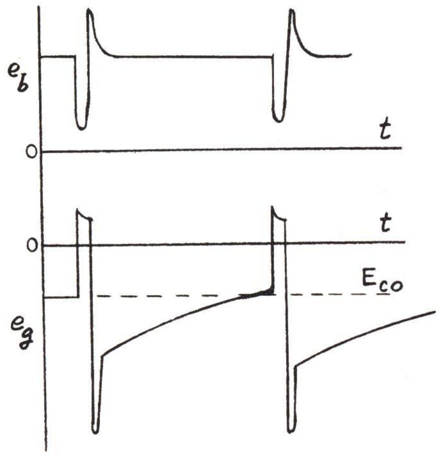

Figure 3-27 - Blocking Oscillator Operating Cycle

is driven positive, two actions occur: Grid current flows and charges C_1; and plate voltage is reduced to such a low value that further increase in grid voltage will not increase the plate current. The secondary voltage then ceases to increase, and C_1 begins to discharge. The discharge of C_1 lowers the grid voltage, causing a decrease in plate current. The induced voltage in the secondary is in the negative direction, due to the change in di_p/dt, and the grid is driven quickly below cut-off. Then C_1 is discharged through R_1 and the transformer secondary until the grid voltage is less than cut-off. When plate current starts to flow, the cycle is repeated. The unbiased blocking time is roughly 2 or 3 times C_1R_1, depending upon the transformer turns ratio, inductance values, and self-resonant frequency. The blocking oscillator frequency may be controlled by varying the bias on the grid or on the cathode, or by varying R_1.

The blocking oscillator may be synchronized by applying either a sine-wave or a pulse voltage across a resistor in the ground lead of the transformer secondary.

STEP-CHARGING CIRCUITS

A step-charging circuit is one in which the potential across a capacitor is built up in a series of steps. Its fundamental use is in a frequency-dividing system in which a blocking oscillator is triggered after a number of steps have been completed. Figure 3-28 shows a simple step-charging circuit and the resultant wave forms.

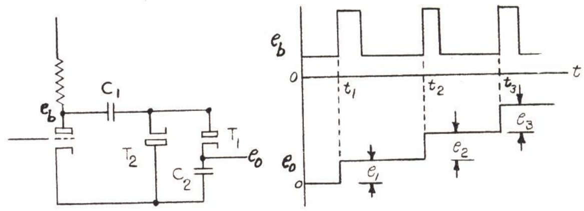

Figure 3-28 - Step-charging Circuit

Assume that the plate voltage e_b rises quickly at time t_1 and that $e_o = 0$. Diode section T_1 will conduct and charge C_1 and C_2. The voltage across C_2 is given by the equation.

$$e_1 = \frac{e_b C_1}{C_1 + C_2}$$

When e_b returns to its minimum value, diode section T_2 will conduct and discharge C_1. At time t_2 diode T_1 conducts again, charging C_1 and C_2. This time, however, the total change in e_b is not divided between C_1 and C_2 since C_2 has on it the voltage developed at time t_1. Let e_1 denote voltage to which C_2 was charged during the initial pulse. Then

$$e_2 = \frac{(e_b - e_1)\, C_1}{C_1 + C_2}$$

Each succeeding step may be calculated in the manner shown above. The voltage on C_2 during the preceding step must be subtracted from the peak-to-peak plate voltage in determining the amplitude of the next step.

At the end of a given number of steps, a blocking oscillator is triggered, C_2 is discharged, and the cycle is repeated.

NON-LINEAR MIXERS

In some television applications, specifically in the synchronizing generator, it is necessary to mix two pulses in such a manner that the resultant signal is not the algebraic sum of the two pulses. In effect, a third pulse is created which differs in character from the original pulses. Consider the circuit in Figure 3-29. The 6L7 tube is biased at such a high value that both grids must receive positive pulses before plate current can flow. During the time that a positive pulse exists on both grids, plate current flows and gives an output voltage as shown.

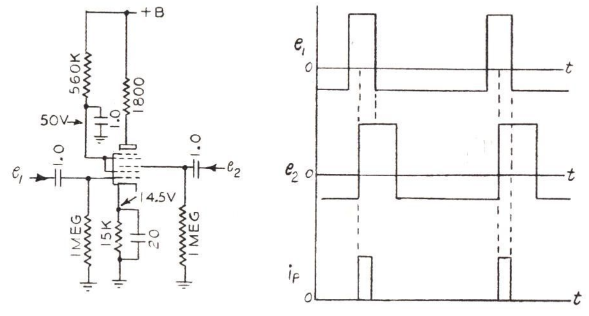

Figure 3-29 - Non-linear Mixer

Figure 3-30 is a curve taken on a type 6L7 tube for the electrode voltages shown. If the bias voltage is set at -14.5 volts as indicated, either grid potential may be reduced to zero without plate current flow.

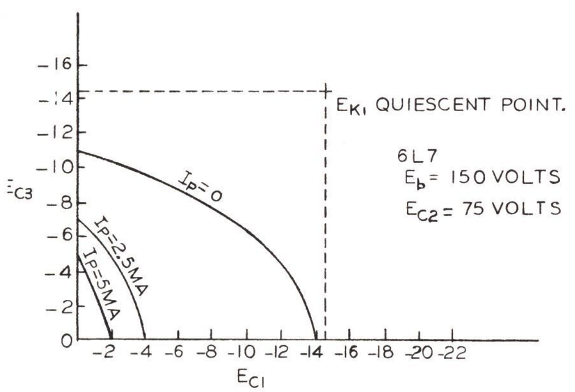

Figure 3-30 - Characteristics of Type 6L7 Tube

A-F-C DISCRIMINATOR CIRCUIT

To improve receiver performance, certain limitations have been recommended by the RMA Committee on Standards for the maximum acceleration of the synchronizing-signal frequency. Also, it is desirable to lock the frequency of the sync generator to a local 60-cycle power supply so as to simplify studio and remote operation. Since the local power-supply frequency may change by an amount exceeding RMA standards during sudden load changes, a means of delayed frequency control must be devised, in which the acceleration of frequency, in cycles per second per second, does not exceed the recommended standard. Such a circuit is the lock-in circuit shown in Figure 3-31.

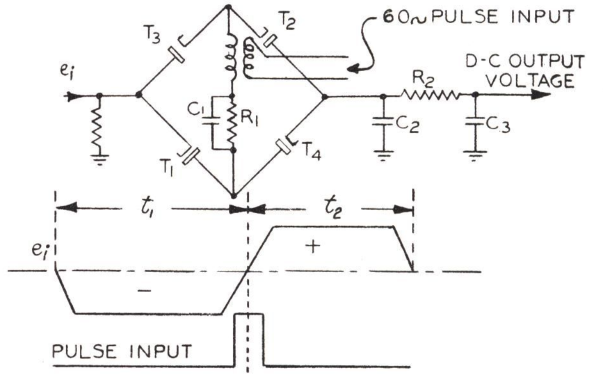

Figure 3-31 - Frequency Control Circuit

The circuit consists of four diode elements in a balanced bridge network. The sine wave of the local 60-cycle supply is clipped and applied across the bridge. A 60-cycle pulse voltage, derived from the synchronizing signal oscillator, is applied to the center leg of the bridge through a transformer. The phase of the local power supply voltage is adjusted so that the pulses occur at the zero-voltage point.

With reference to Figure 3-31 it may be seen that, normally, T_1 and T_2 would conduct during the negative half-cycle; however, a bias voltage, built up across R_1C_1, prevents conduction. Similarly, T_3 and T_4 would normally conduct during the positive half-cycle, except for the bias voltage. The pulse voltage overcomes the bias voltage when the clipped sine wave is passing through zero, and T_1 and T_2 conduct briefly during a small portion of the negative half-cycle, while T_3 and T_4 conduct momentarily during a small portion of the positive half-cycle. If the pulse voltage is in phase with the power line voltage and of the same frequency, the net charge on C_2 will remain the same.

If, however, the frequency relationship between C_1 and the pulse voltage should change, the charge on C_2 will change because the diodes will conduct more during one of the half-cycles than during the other. The time constant of R_2C_3 may be adjusted to provide for slow changes in the d-c output voltage, thus preventing erratic changes in power-line frequency from appearing in the control voltage.

The d-c output voltage is used to control a reactance tube for changing the frequency of the pulse voltage.

REACTANCE TUBE CIRCUIT

A reactance tube is used for controlling the frequency of an oscillator by varying the effective tank circuit in the plate of the oscillator. Figure 3-32 shows a typical reactance tube circuit.

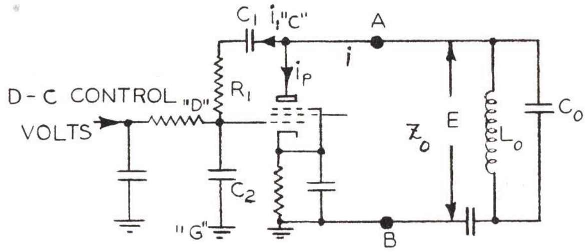

Figure 3-32 - Reactance Tube Circuit

In this circuit, $R_1 >> 1/j\omega C_1$. Let the impedance between points "*C*" and "*D*" be $Z_1 = R_1$. The impedance from "*D*" to "*G*" is $1/j\omega C_2$, which we shall call Z_2. Then we may draw the equivalent circuit shown in Figure 3-33.

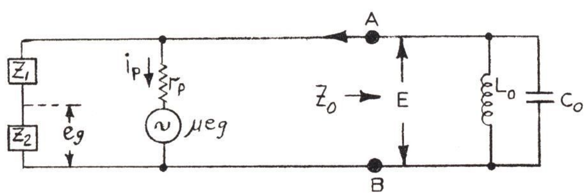

Figure 3-33 - Reactance Tube Equivalent Circuit

If $\quad Z_1 >> Z_2, \; e_g = \dfrac{E\,Z_2}{Z_1 + Z_2} \approx \dfrac{E\,Z_2}{Z_1}$

If $\quad Z_1 + Z_2 >> r_p, \; i_p \approx i$

but $\quad i_p = g_m e_g = \dfrac{g_m Z_2 E}{Z_1}$

The admittance, looking into the reactance tube plate is

$$Y_{AB} = \frac{i}{E} \approx \frac{g_m Z_2}{Z_1}$$

or

$$Y_{AB} = \frac{g_m}{j\omega C_2 R_1}$$

Thus, the admittance of the reactance is equivalent to an inductance which would vary with g_m. The vector diagram of current and voltage relationships is shown in Figure 3-34.

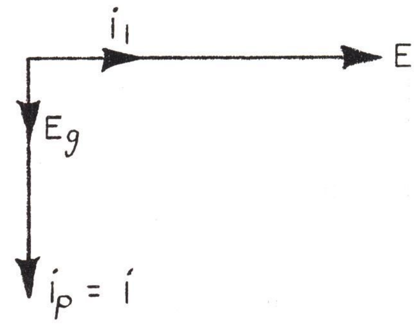

Figure 3-34 - Reactance Tube Circuit Vector Diagram

Mutual conductance of the reactance tube is varied by changing the d-c grid bias. This circuit, in conjunction with the lock-in circuit previously described, may be used to keep the frequency of an oscillator synchronized to a local power source.

SAWTOOTH GENERATORS

A sawtooth generator is a device whose output voltage has a repeating triangular wave shape of which the positive slope is constant. Thus

$$\frac{de}{dt} = Constant$$

This type of voltage is used as a time base for the scanning of cathode-ray or kinescope tubes. In view of the present television standards, we shall be concerned with sawtooth wave forms whose frequencies are 60 cycles and 15,750 cycles per second.

Figure 3-35 is a circuit diagram of a sawtooth generator commonly used in television equipment.

Assume that *C* is charged at the beginning of a cycle. Pulse e_i is applied to the grid

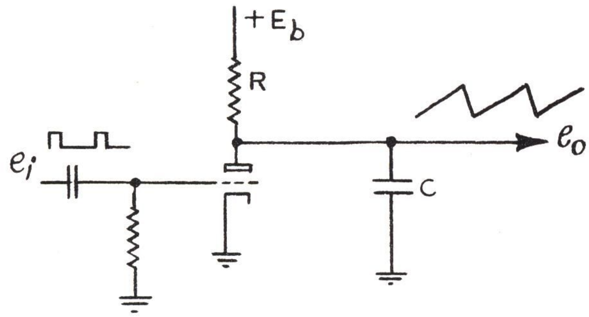

Figure 3-35 - Sawtooth Generator Circuit

with sufficient amplitude to drive the grid positive. The triode conducts heavily, discharging C. During the positive pulse interval, the flow of grid current produces a bias voltage across the grid resistor, of sufficient amplitude to cut the tube off when the pulse goes negative. Capacitor C charges exponentially through resistor R while the tube is cut off between pulses.

In the analysis of the sawtooth generator, certain assumptions will be made. First, we shall assume complete discharge of C during the pulse. Usually $\bar{r}_p << R$ and t_1 is long enough to permit the voltage across C to discharge to $E_b\bar{r}_p/(\bar{r}_p + R)$. With $\bar{r}_p << R$, we have $e_1 \approx 0$.

Now we shall define a linearity factor λ. Consider Figure 3-36 in which we have a linearly increasing voltage of constant slope de/dt. Such a voltage may be obtained by making the charging current constant, or

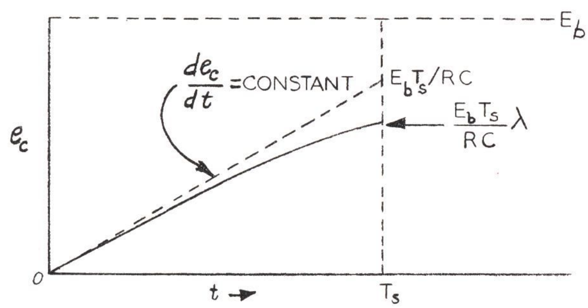

Figure 3-36 - Analysis of Sawtooth Voltage

$$e_c = \frac{1}{c}\int_0^t i\,dt$$

$$= \frac{i}{c}\,t$$

$$= \frac{E_b\,t}{RC}$$

In the ordinary sawtooth generator circuit, the charging current is not constant, but varies exponentially so that the voltage on C at the time T_s is less than the voltage for the ideal case by a factor λ, or

$$e_c = \frac{E_b\,T_s}{RC}\,\lambda$$

The linearity factor λ is thus expressed as the percentage of ideal voltage to which C charges in a simple circuit.

From the simple circuit we know that

$$e_c = E_b(1 - \epsilon^{-T_s/RC});$$

hence

$$\lambda = (1 - \epsilon^{-T_s/RC})\frac{RC}{T_s}$$

If we expand the exponential term about zero by means of a McLaurin's series we obtain

$$\lambda = [1 - (1 - \frac{T_s}{RC}) + (\frac{T_s}{RC})^2\frac{1}{2} - (\frac{T_s}{RC})^3\frac{1}{6} + (\frac{T_s}{RC})^4\frac{1}{24} + \ldots]\frac{RC}{T_s}$$

$$= 1 - (\frac{T_s}{RC})\frac{1}{2} + (\frac{T_s}{RC})^2\frac{1}{6} - (\frac{T_s}{RC})^3\frac{1}{24} + \ldots]$$

Let us take the first two terms and rearrange

$$\frac{2}{\lambda} - 2 = \frac{T_s}{RC}\,\frac{1}{\lambda}$$

If we restrict the value of λ to the limits 0.75 to 1, we may write

$$\frac{T_s}{RC} \approx \frac{2}{\lambda} - 2$$

Substituting, we obtain

$$e_c \approx E_b \left(\frac{2}{\lambda} - 2\right) \lambda$$

$$\approx 2\, E_b (1 - \lambda)$$

The preceding equations are useful for determining the charging time constant and output voltage for a given supply voltage and linearity requirement. The linearity factor usually varies from 0.90 to 0.95.

BLOCKING OSCILLATOR SAWTOOTH GENERATOR

The sawtooth generator described above requires a pulse driving signal of fairly good rectangular wave shape. If the driving pulse fails, no sawtooth output is obtained. A blocking oscillator can be used as a sawtooth generator to provide output voltage even though the synchronizing source may fail. Figure 3-37 is a circuit diagram of such a generator

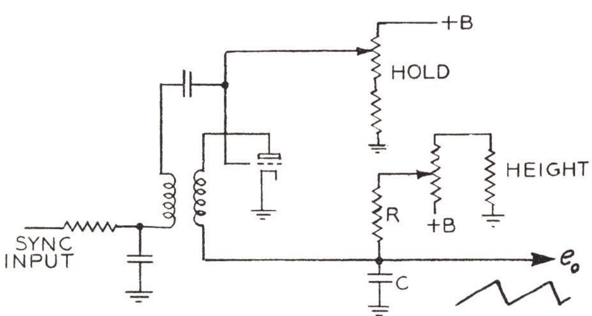

Figure 3-37 - Blocking Oscillator Sawtooth Generator

In this circuit, *R* and *C* form the sawtooth through the charging and discharging action of the tube. Assume that *C* is charging through *R*. Then the blocking oscillator conducts heavily, discharging *C*. When the grid is driven below cut-off, the tube ceases conduction, and *C* charges through *R*. The blocking oscillator is synchronized by a pulse signal whose wave form need not be rectangular. Frequency is adjusted to the synchronizing signal by the "hold" control. Amplitude of the sawtooth is adjusted by the "height" control.

LINEARITY

The linearity of the output voltage from the conventional sawtooth generators described above varies with the time constants used; and the voltage always is an exponential, instead of a linear, function of time. Special methods may be applied to improve the linearity of the sawtooth. One means by which linearity may be corrected is shown in Figure 3-38.

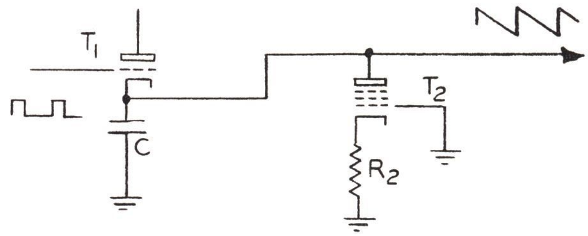

Figure 3-38 - Sawtooth Linearity Circuit

In this circuit *C* is charged during the input pulse and discharged through a constant-current pentode T_2. Since the discharge current is very nearly constant, the voltage on the capacitor becomes.

$$e_c = -\frac{1}{c}\int_0^t i\, dt$$

$$= \frac{Kt}{c}$$

The plate resistance of the pentode can be increased by using a large cathode resistor R_2, thus increasing the effective plate resistance by $1/(1 - g_m R_2)$

It will be noted that the output is inverted from the conventional sawtooth generator.

By the use of feedback to the pentode of Figure 3-38, a perfect sawtooth may be obtained. In Figure 3-39 a portion of the sawtooth output

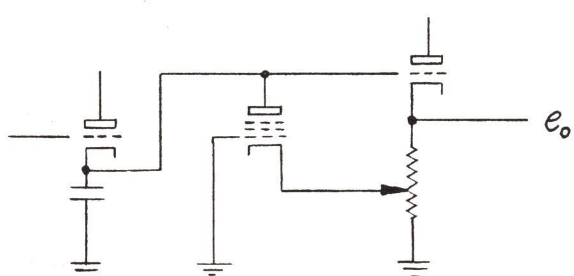

Figure 3-39 - Linearity Feedback Circuit is fed back to the cathode of the constant-current pentode. The effective plate resistance is high as *C* begins to discharge, and decreases as the discharge proceeds. Not only may a linear sawtooth be obtained, but a strong overcorrection may be attained.

These, and other methods of linearity correction, are described in the December 1946 issue of "Electronics" in the paper "Linear Sweep Circuits" by Robert P. Owen.

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Puckle, O.S., *Time Bases*, John Wiley and Sons, Inc., New York, 1943

Owen, Robert P., "Linear Sweep Circuits," *Electronics*, December, 1946

Brainerd, J.G., *Ultra-high Frequency Techniques*, D. Van Nostrand Company, Inc., New York, 1942.

MAGNETIC DEFLECTION

Deflection of the electron beam in kinescope and camera tubes is accomplished by a uniform magnetic field at right angles to the tube axis. When it travels through the magnetic field, the electron is subjected to a transverse force which causes it to move along an arc of a circle. On leaving the magnetic field, the electron continues along a straight line which is tangent to the arc at the field boundary, as shown in Figure 3-40. The electron emerges from

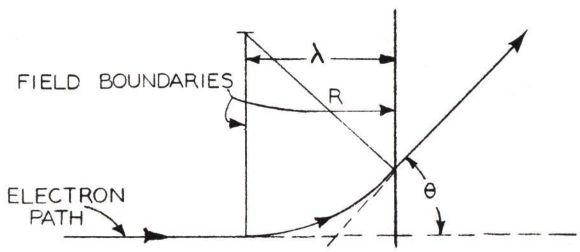

Figure 3-40 - Electron Path at Field Boundary

the field at an angle θ with respect to the original direction of motion. The total angle of deflection is 2θ. In present-day kinescope tubes, the maximum angle of deflection is 50° and is limited by inside neck diameter and length of field λ.

The magnetic field required for deflecting the electron beam in a television kinescope or pick-up tube is produced by passing a sawtooth current through a pair of series-connected coils on opposite sides of the tube neck. Formerly, the coils which make up the yoke were wound on a flat rectangular template, and then formed around a cylinder of a diameter equal to, or greater than, the tube neck. Present coils are machine-wound, and the cylindrical forming occurs during the winding process. Figure 3-41 is a rough sketch of a modern yoke winding.

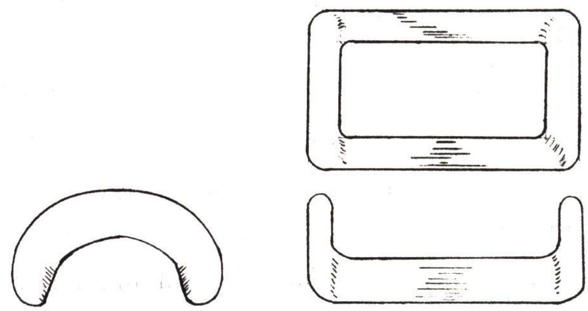

Figure 3-41 - Deflection Yoke Winding

The number of ampere-turns required to produce a given angle of deflection is calculated from

$$NI = \frac{2.68\, l_o \sin\theta \sqrt{E_a}}{\lambda}$$

where
NI = ampere-turns of winding
l_o = length of air gap, inches
λ = length of magnetic field, inches
θ = 1/2 total deflection angle
E_a = accelerating potential, volts.

Note that the above value NI is for half the total deflection angle. To obtain NI for the total deflection angle, multiply by 2.

For a standard 4:3 aspect-ratio television raster, the value of the horizontal-winding ampere-turns is

$$(NI)_H = 0.8\, NI$$

while for the vertical winding it is

$$(NI)_V = 0.6\, NI.$$

VERTICAL DEFLECTION CIRCUIT

Figure 3-42 shows a vertical deflection circuit in its simplest form. The vertical yoke

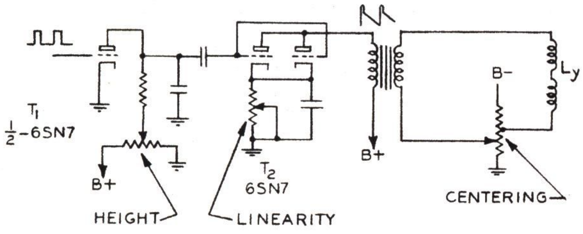

Figure 3-42 - Vertical Deflection Circuit

winding is transformer-coupled to a 6SN7 triode, T_2, with both sections parallel-connected. The driving sawtooth is generated in a conventional sawtooth generator, T_1.

Practical values for the vertical winding of the yoke are L = 43 millihenrys and R = 70 ohms. At the vertical scanning frequency the load impedance becomes

$$Z_y = 70 + j18.1$$

In the design of the transformer and driving circuit, the inductive component of the load is neglected. The problem then becomes one of designing a transformer which will match the yoke resistance to the driver tube and present sufficient primary inductance for good low-frequency response. A type 6SN7 triode provides sufficient output to deflect a 9-kv beam. The plate resistance of the 6SN7, parallel-connected, is approximately 3500 ohms. For maximum power output, the load should be $2r_p$; therefore the reflected load of the yoke should appear as 7000 ohms on the primary side. The transformer turns-ratio becomes

$$N_p/N_s = \sqrt{Z_p/Z_s} = \sqrt{7000/70} = 10/1.$$

Good low-frequency response is obtained by making the primary inductance large. In the RADIOTRON DESIGNER'S HANDBOOK the ratio of low-frequency gain to mid-band gain is given as

$$A_r = \frac{1}{\sqrt{1 + (r_p/L_p)^2}}$$

If the response at 60 cycles is to be 1 db down. A_r becomes 0.89, from which

$$L_p/r_p = 1.94.$$

For the circuit of Figure 3-42 the primary inductance should be 18 henrys. Actually, for standard vertical-deflection transformers, L_p varies from 40 to 60 henrys.

Some control of linearity may be obtained by varying the bias voltage of T_2. Usually, the sawtooth amplitude and bias are adjusted together to place the operating point in the most linear portion of the tube curves.

The picture is centered by adjusting the centering potentiometer so that a steady d-c current flows in the yoke. Current may be caused to flow in either direction to move the picture in either direction.

No external damping of the yoke winding is required, in the majority of cases, since the plate resistance of the tube is reflected to the transformer secondary. If external damping is required, a resistor of proper value may be placed across the yoke winding.

AUTOMATIC LINEARITY CONTROL

Picture linearity may be corrected by the linearity correction devices previously discussed. Additional tubes and circuit components are required, however, and if the expense is justified, an automatic control may be used.

Figure 3-43 shows an automatic linearity control circuit recently developed by the Advanced Development Section, Home Instruments Department.

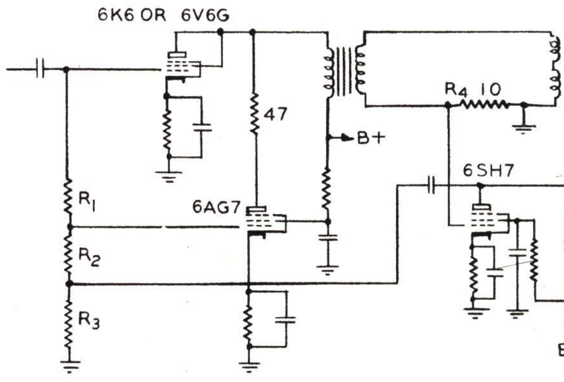

Figure 3-43 - Automatic Linearity Control Circuit

The circuit operates as follows. A pilot voltage is developed across R_4 in the yoke circuit, which is proportional to the current in the yoke. This voltage contains the distortion of the current sawtooth and is shown in Figure 3-44(a).

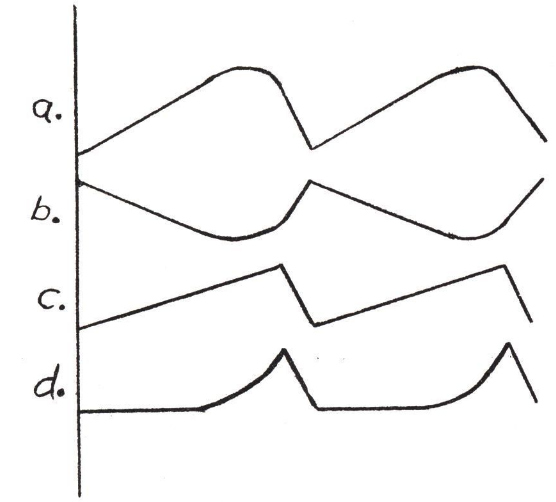

Figure 3-44 - Sawtooth Linearity Control
a. *Current Sawtooth Containing Distortion*
b. *Plate 6SH7 Sawtooth Plus Distortion*
c. *Input Sawtooth*
d. *Grid 6AG7 Distortion Only.*

The distorted sawtooth is amplified in a high-gain pentode and fed to the top of R_3. A sawtooth of good linearity is fed into the driver tube, 6K6 or 6V6, and also to R_1. In the resistance network $R_1 R_2$ the linear sawtooth is compared to the distorted sawtooth, and the existing distortion is placed on the grid of the 6AG7. The distortion signal causes the plate of the 6AG7 to draw a current which cancels the original distortion.

In this system, picture size may be changed over wide limits with negligible vertical distortion. The values of R_1 and R_2 should be less than one-half megohm to prevent integration of the linear sawtooth.

HORIZONTAL DEFLECTION CIRCUITS

Circuit design for magnetic deflection of the electron beam at horizontal-line frequencies requires a different approach than for vertical deflection. At 15,750 cycles per second, the yoke presents a load which is almost entirely reactive. Unless means are devised to recover a portion of the power fed into the yoke during trace time, a relatively high amount of power must be expended in deflecting the beam. An ideal cyclic system such as that discussed by Otto Schade in RCA REVIEW for September, 1947, requires wattless power. This system will form the basis for study of the horizontal-deflection problem.

Consider the simple circuit of Figure 3-45, The yoke is represented by L_y, C_y, R_y. Suppose that switches S_1 and S_2 are open at the time $t = 0$. At the beginning of the deflection cycle, S_1 is closed, applying voltage E across L_y, R_y, and C_y. If it were not for R_y, the current through L_y would increase linearly with time, as expressed by the relation

$$\frac{di}{dt} = \frac{E}{L}.$$

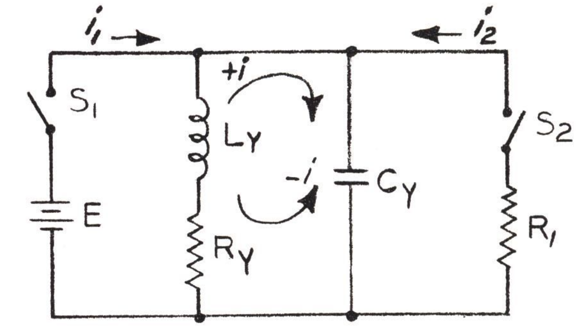

Figure 3-45 - Equivalent Horizontal Deflection Circuit

Since R_y is present, the current rises exponentially until switch S_1 is opened. At this point, the beam has been deflected to the right-hand side of the picture. The magnetic field must be reversed quickly in order to return the beam to the left-hand side of the picture, to begin another trace.

Since L_y, C_y, and R_y form a resonant circuit, the fastest means for reversing the field is to permit the winding to oscillate for approximately one-half cycle at its natural resonant frequency.

When S_1 is opened, the magnetic energy stored in the field of L_y is converted into potential energy by the flow of $+i$ into C_y, and back into magnetic energy by the flow of $-i$, resulting in an almost complete reversal of the field. Losses in the resonant circuit limit the completeness of reversal to

$$\frac{i_1}{i_2} \approx \epsilon^{-\pi/2Q}$$

Figure 3-46 indicates the current and voltage waveshapes in the yoke for a complete deflection cycle.

When the current in the yoke has reached the value $\hat{i}_2$ in the negative direction, switch S_2 is closed, which places damping resistor R_1 across

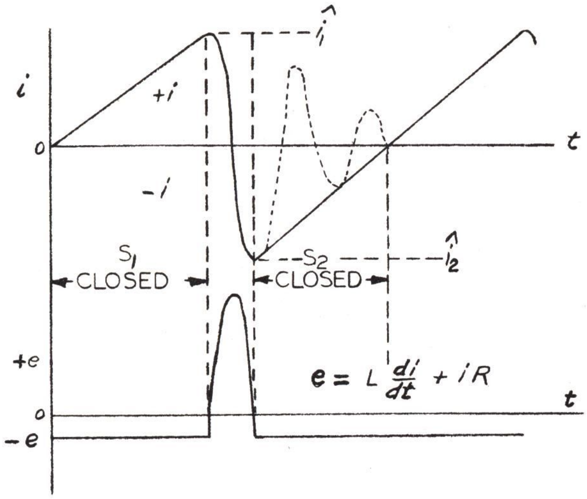

Figure 3-46 - Deflection-cycle Waveshapes

the oscillating circuit. If S_2 were not closed, the yoke would continue to oscillate, as shown by the dotted lines in Figure 3-46. Closing of S_2 causes the oscillatory circuit to be slightly overdamped, so that $-i$ decays exponentially. When $-i$ reaches zero, S_1 is closed again to begin another cycle.

Because of the presence of the iR drop in the inductance, the resultant current wave form in the yoke is exponential instead of being linear with time, as desired. If the iR drop can be canceled, the total voltage E may be applied to L_y, resulting in a linear current in the yoke. Suppose we insert a generator in series with E, whose characteristic is

$$\frac{\Delta e}{\Delta i} = -R .$$

Then a linear rise of current in L_y may be obtained. Reference to the plate-family of curves for a vacuum tube reveals that a tube may serve as such a generator and as an electronic switch to replace S_1. Also, we may use a vacuum tube to replace S_2 and add $-R$ for the oscillatory phase. Such a circuit is shown in Figure 3-47.

The operation of the tube may be plotted from its family of curves. Refer to Figure 3-48. The load line $-R$ is so drawn that it intersects the plate-voltage, or zero-current, axis at the point $E - L\,di/dt$. A plot of current-versus-time is obtained from the intersection of the $-R$ line with the grid-voltage lines. The grid-voltage waveshape e_g is obtained for the tube

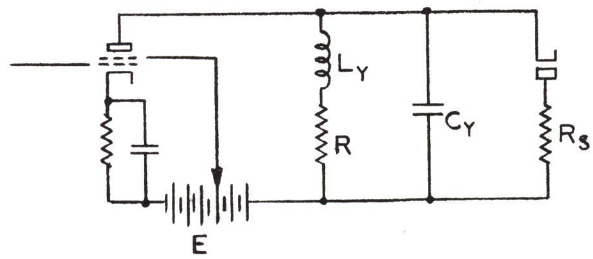

Figure 3-47 - Electronic Switch and Generator Circuit

by plotting E_{c1} against time for corresponding values of current i.

The diode characteristic is plotted in a similar manner. The voltage causing diode conduction, however, becomes $L\,di/dt$ and is equal

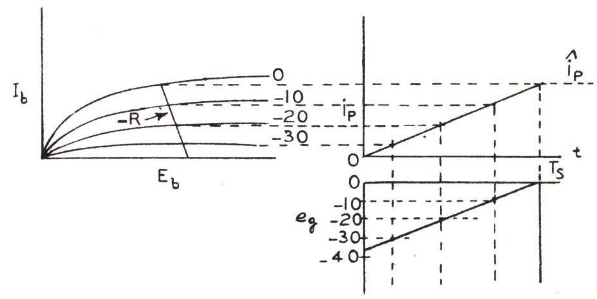

Figure 3-48 - Tube Operating Curves

to the drop across the inductance during trace time. The load line for the diode must be drawn for $r_d + R_s$, where r_d is the diode resistance. Schade states that linearity in the diode circuit occurs when

$$R_s = [E - (\hat{i}_1 R + E_d)]/\hat{i}_2 .$$

The circuit operation may be improved by replacing the diode with a controlled triode. For simplification, a transformer is added, and the circuit becomes the one shown in Figure 3-49.

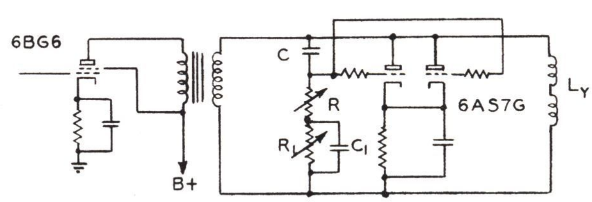

Figure 3-49 - Improved Switching Circuit

The combined characteristics of the beam tetrode and the triode are shown in Figure 3-50. Note that the characteristics resemble those of the ordinary push-pull arrangement.

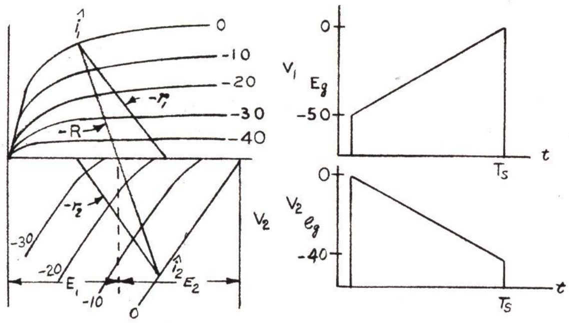

Figure 3-50 - Combined Characteristics of Beam Tetrode and Triode

In the ideal case, in which there are no losses, the 6BG6 driver tube supplies half the deflection current, and the 6AS7 triode damper supplies the remainder from the stored energy. Such utilization of current is shown in Figure 3-51. Because of losses in the actual circuit, the driver tube must supply about 60% of the total deflection current.

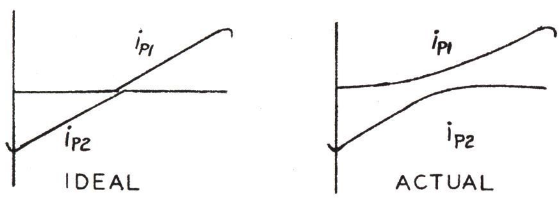

Figure 3-51 - Deflection Circuit Operation

The control-grid voltage for the triode damper is generated by differentiation of the pulse voltage across the yoke. The values of *RC* are determined by the equation

$$\frac{T_s}{R_c} \approx \frac{2}{\lambda} - 2$$

where λ = linearity of voltage rise = 0.3 to 0.8.

Usually *R* is made variable for adjusting linearity.

The combination $R_1 C_1$ has a long time-constant and is placed in the grid circuit for establishing grid bias for the triode by the flow of grid current on the peaks of the grid voltage.

REFERENCES

Maloff, I. G., and Epstein, D. W., *Electron Optics in Television*, McGraw-Hill Book Co., Inc., New York, 1938.

Schade, O. H., "*Magnetic Deflection Circuits for Cathode-Ray Tubes*," RCA Review, September, 1947.

VIDEO AMPLIFIERS

REQUIREMENTS - The nature of the picture signal imposes certain requirements upon the video amplifier, which must be met if fine picture detail is to be resolved. First, the bandwidth must satisfy the relation

$$f_n = A_r\, n\, \frac{10^6}{H_a \times 2}$$

where f_n = fundamental frequency for *n* lines
A_r = aspect ratio = 4/3
n = number of lines to be resolved
H_a = active trace time, microseconds.

Since horizontal blanking occupies 16% of the horizontal period, the active trace time, H_a, is 0.84 × 63.5 = 53.3 microseconds. To resolve 400 lines, the bandwidth must be

$$f_n = \frac{4}{3} \times \frac{400 \times 10^6}{53.3 \times 2} = 5 \text{ megacycles}$$

In practice, the output of the video transmitter is specified by standards to include all frequencies between 30 cps and 4 megacycles per second. Hence, the video amplifier must amplify, without discrimination, at least those frequencies between 30 cps and 4 megacycles per second. Usually, the video amplifier is designed with a bandwidth exceeding these limits.

Also, the video amplifier must have a minimum time-delay discrimination. This requirement is fulfilled when the phase angle between input and output voltages is proportional to frequency.

Finally, there are requirements for the video amplifier which are set by standards or practice, some of which are output-voltage levels, terminal impedances, permissible signal-to-noise ratio, etc.

FREQUENCY RESPONSE - Low-frequency response of an RC-coupled amplifier is determined by the time-constant of the coupling capacitor and grid-leak resistor. In practice, good low-frequency response is obtained by making the time-constant large or by using clamp circuits.

High-frequency response is limited by shunt capacity across the plate-load resistor. This shunt capacity includes the tube input and output capacity, wiring capacity, and stray capacity of circuit components. Good high-frequency response is obtained by utilizing the various shunt capacities as elements of a low-pass coupling filter.

Figure 3-52 is a diagram of a constant-K low-pass filter consisting of one full section and one half-section terminated in its characteristic impedance.

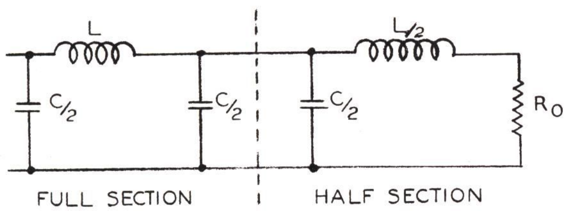

Figure 3-52 - Constant-K Low-pass Filter

The terminating half-section is added for impedance matching purposes. When the low-pass filter is properly designed and terminated, the characteristic impedance is constant to almost the cut-off frequency. Connection of the coupling filter to the amplifier tubes is shown in Figure 3-53. In Figure 3-53

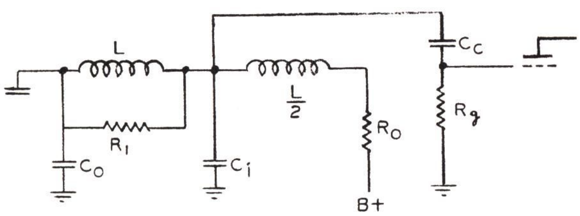

Figure 3-53 - Coupling Filter-connection

C_o and C_i are output and input capacities of the tubes. For this particular type of low-pass filter, the following equations apply:

$$f_c = \text{cut-off frequency}$$

$$R_o = \frac{1}{\pi f_c C_i}$$

$$L = R_0^2 \; C_i$$

$$C_o = \frac{C_i}{2}$$

$$R_1 = (5 \text{ to } 10) \; R_o$$

$$A = g_m R_o$$

The resistor R_1 is added to lower the Q-factor of the series inductance. A peak in the response curve will result prior to cut-off if the Q-factor is not optimum.

The characteristics of the constant-K low-pass filter depend upon the components being pure inductances and pure capacitances. It has been shown that distributed coil capacity converts the constant-K type into an M-derived filter, as shown in Figure 3-54.

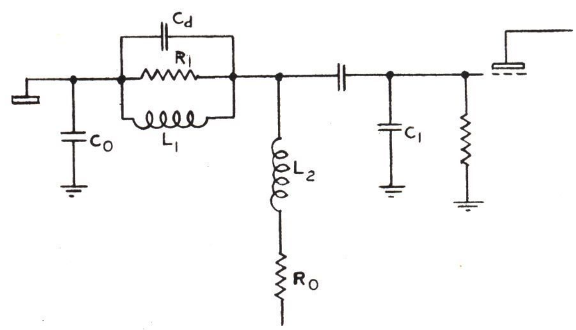

Figure 3-54 - Effect of Coil Capacity on Constant-K Filter

Equations for the M-derived filter are as follows:

$$M = \sqrt{1 + \left(\frac{C_d}{C_o}\right)^2} - \frac{C_d}{C_o}$$

$$R_o = \frac{M}{\pi f_c C_i}$$

$$L_1 = R_0^2 \; C_i$$

$$L_2 = 0.8 \; L_1 \; \textit{approx.}$$

$$R_1 = (5 - 10)\ R_o$$

$$A = g_m R_o$$

Practical video amplifiers use the M-derived low-pass filter as a means of coupling amplifier stages.

Diagnosis curves are given in Figures 3-55 and 3-56 to aid in the alignment of video amplifiers using low-pass filter coupling.

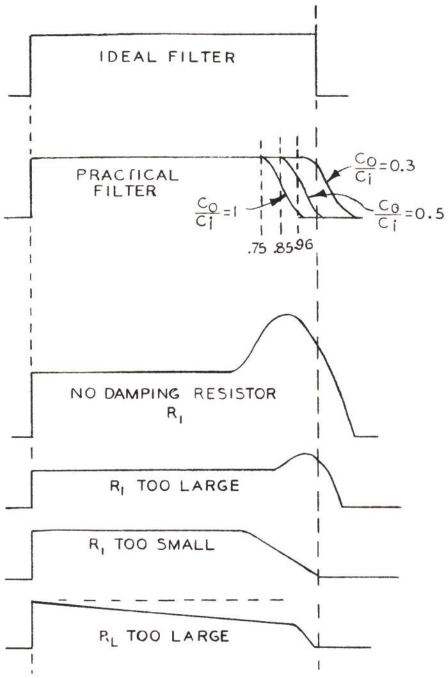

Figure 3-55 - Diagnosis Sheet #1

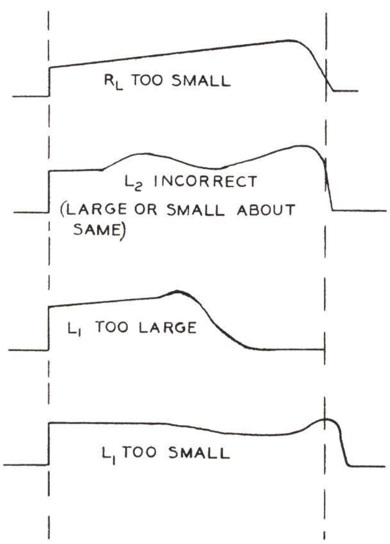

Figure 3-56 - Diagnosis Sheet #2

CLAMP CIRCUITS

The clamp circuit is often used as a "D-C Restorer"; however, it can also be used to restore low frequencies in a video amplifier. Its operation in the latter application will be described first.

Consider the video signal for a half-black, half-white picture applied to the input of a video amplifier whose frequency response is very poor below the horizontal-scanning frequency. Assume that horizontal blanking pulses are also introduced at the amplifier input, and that they are of greater amplitude than any other part of the video signal. A sketch of the picture and the corresponding video signal with horizontal blanking is shown in Figure 3-57.

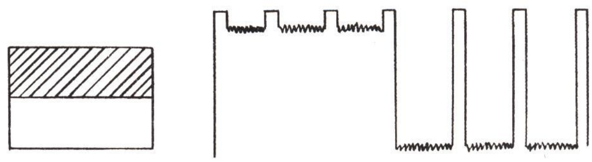

Figure 3-57 - Half-black, Half-white Picture and Video Signal

After this signal has passed through the amplifier, the low-frequency components will be missing, and the signal will distribute itself about an a-c axis as shown in Figure 3-58. Low-frequency components are, in this case, considered to be any components of less than the horizontal scanning frequency. The transitory periods immediately following the change from black to white are not shown in Figure 3-58.

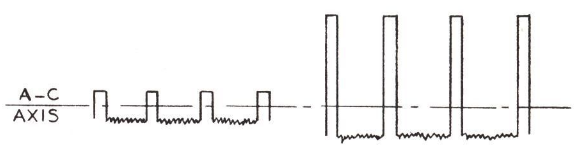

Figure 3-58 - Video Amplifier Output Signal

Note that, if we could bring the peaks of the horizontal blanking pulses that occur during the "black" portion of the picture to the same level as the peaks of those that occur during the "white" portion, the signal would again be identical to that in Figure 3-60. In other words, the low-frequency components would then be restored because the output signal would be similar in shape to the input signal.

Figure 3-59 shows a hypothetical circuit for bringing all of the blanking pulses to the same level. The time-constant of R and C must be sufficiently small so that *C* is discharged before the blanking pulse is over. The switch is so controlled that it closes at the start of the blanking pulse and opens *before* the end of the pulse. Because of these conditions (grid of the tube floating during the time the switch is open, grid-side of *C* being always brought to ground potential during the pulse, and switch opening before the pulse is over), *the remaining portion of the pulse always falls at the same point on the tube's operating characteristic.* As explained in the preceding paragraph, this is equivalent to restoring the low-frequency components.

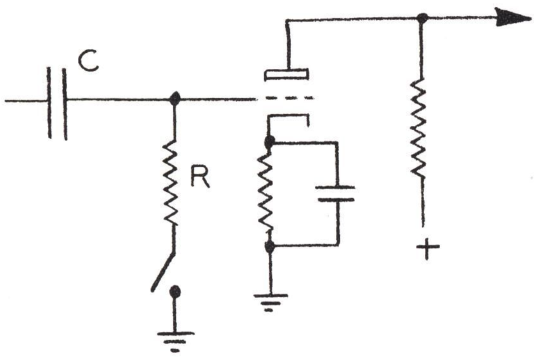

Figure 3-59 - Simplified Clamp Circuit

A clamp circuit, shown in Figure 3-60, is electrically equivalent to the arrangement of Figure 3-59. The diodes replace the switch of Figure 3-59, and the switch control is supplied by the diode keying pulses. The circuit "clamps" on the periodic pulses in the video signal, which in the given example are horizontal blanking pulses; hence its name.

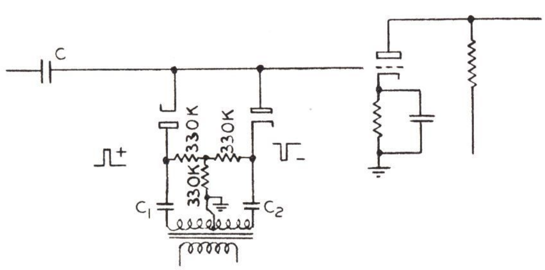

Figure 3-60 - Clamp Circuit

The keying pulses (which should not be confused with the clamp pulses) are 180 degrees out of phase, so that both diodes become conducting simultaneously. By using this balanced arrangement, the keying pulses cancel out at the grid of the amplifier tube, and are therefore not added to the desired signal. It is essential that the keying pulses end before the clamp pulses, as explained above. Horizontal synchronizing signal makes ideal keying pulses. The amplitude of the keying pulses must also be greater than the clamp pulses, so that the diodes can be made conducting during keying time. Practice has shown that the keying pulses should be one-and-a-half to two times as large as the clamp pulses.

It is important to note that pulses other than horizontal blanking can be used to clamp on. The only requirements are that they be greater in amplitude than any other part of the video signal, that their peaks represent constant amplitude in the input signal, and that their frequency be sufficiently high for the amplifier to pass them without frequency or phase distortion. Of course, they must not interfere with the desired signal. Hence, for television work, they must occur at horizontal scanning frequency, and during horizontal blanking time. Their polarity, with respect to the video signal, is unimportant.

The coupling capacitor *C* and the resistance between grid and ground during keying time must have a sufficiently small time-constant for *C* to discharge during keying time. For 15-kc clamp pulses, the value of *C* can be between 100 and 500 $\mu\mu f$. The coupling capacitors, C_1, and C_2, are also somewhat critical because the diodes are self-biased by them and their associated "leak" resistors. The bias developed is proportional to the amplitude of the keying pulses, in a manner similar to that of a conventional diode detector. Values for C_1 and C_2 are best determined by experiment. Values which have been used in the past lie between 0.003 μf and 0.1 μf for the leak resistances shown.

In some cases it may be desirable to return the grid of the amplifier tube to a fixed-bias source instead of to ground. The bias source is then introduced in series with the ground lead shown in Figure 3-60.

The source of the keying pulses is of importance. A center-tapped transformer is desirable because it provides balanced pulses easily, and the source-impedance is low. A tube with load resistors in both plate and cathode circuits (cathode-follower type of phase inverter) can be used to provide keying pulses. This tube should preferably operate with a negative-polarity pulse on its grid, so that the tube is cut off during keying time. Otherwise, the source-impedance will be different for the positive and negative output pulses, due to cathode-follower action. An unbalance in the source-impedance may adversely affect the operation of the clamp circuit.

The clamp circuit can be modified to advantage when only single-polarity keying pulses

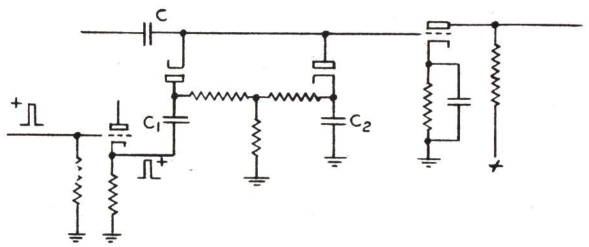

Figure 3-61 - Clamp Circuit for Single-polarity Keying Pulses

are available. This is shown in Figure 3-61. In this circuit, a single keying pulse makes both diodes conducting because they are in series, as far as the keying pulse is concerned. The disadvantage of this circuit is that a small amount of the keying pulse is super-imposed on the video signal because of the unbalance. When horizontal sync pulses are used as keying pulses, this circuit will add a small amount of sync to the video signal; this will some times be an advantage rather than a disadvantage. If vertical sync is unavoidably present along with the horizontal, the coupling capacitors C_1 and C_2 should be increased to 0.5 μf.

Another version of the clamp circuit is shown in Figure 3-62. Only single-polarity keying pulses are required. The source-impedance of the keying pulses can be high, but the circuit provides a low-impedance path between grid and ground during keying time.

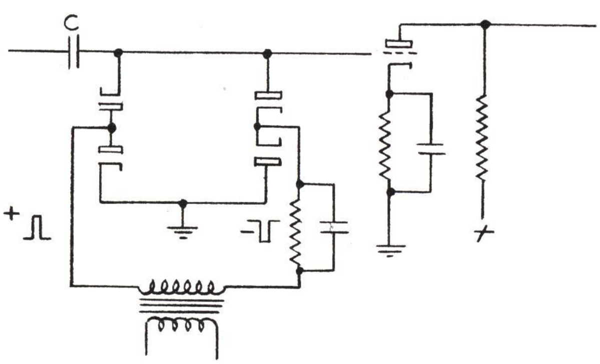

Figure 3-62 - Clamp Circuit for Single-polarity Keying Pulses

THE CLAMP CIRCUIT AS A D-C RESTORER

Since, as was just shown, the clamp circuit effectively restores low frequencies, the same reasoning can be extended to say that the clamp circuit will also restore the d-c component of the video signal. Without d-c restoration, the a-c axis of any signal will pass through the operating point of the tube characteristic to which that signal is applied. However, when the clamp circuit is used on the grid of an amplifier tube (or kinescope), the clamp pulses in the signal are always referred to the same point on the characteristic, regardless of signal amplitude or wave form. In other words, the a-c axis is shifted as the signal amplitude and wave form vary, and a shift in the a-c axis of a wave is equivalent to adding a d-c component. The clamp circuit has the advantage over the simple, single-diode type of d-c restorer in that it responds very quickly to signal changes, whether they be increasing or decreasing; whereas the simpler type has appreciable time lag when the signal suddenly decreases.

PICK-UP TUBES

TYPES - Two types of pick-up tubes are in general use today, namely, the iconoscope and the image orthicon. The iconoscope dates back to about 1923, when it was developed by Dr. V. K. Zworykin. It is still being used for motion-picture pick-up. The image orthicon has replaced the iconoscope for live-talent pick-up. Image-orthicon development was hastened by wartime requirements, and progress on the stabilization and improvement of this tube has been rapid.

ICONOSCOPE - The iconoscope pick-up tube may be used where the scene is illuminated by incident light of approximately 1500 foot-candles. Under ideal lighting conditions, the pictures obtained have excellent resolution and low noise-level. The intensity of illumination, however, limits the use of the iconoscope for outdoor events. When incandescent lighting is used in studios, the problem of removing the heat arises. At present, the iconoscope is used in film cameras only where the motion-picture projector provides ample illumination on the iconoscope mosaic.

The iconoscope contains a photo-sensitive mosaic, a collector ring, and an electron gun. A sketch of the tube is shown in Figure 3-63. The electron gun is set at an angle with the mosaic in order to clear the front of the tube, so that an optical image may be focused on the mosaic.

A uniform mica plate, 0.001 inch thick, is the basic structure upon which the mosaic is constructed. A fine coating of silver oxide is sifted upon the mica. Then, the structure is baked in an oven. The heat produces pure silver from the silver oxide. The pure silver congeals into thousands of small droplets. Then the mica plate is placed in the presence of cesium vapor and oxygen, and a glow discharge is passed through the tube. Silver oxide, cesium oxide, and pure cesium are formed. By this process, small photo-sensitive islands are formed on the mica. The mosaic is completed by coating the back side of the mica with colloidal graphite to form the signal plate which is capacity-coupled to the photo-sensitive surface. Better color response is obtained by the process of silver sensitizing, in which a small particle of pure silver is heated in a filament while the tube is on the pumps. Silver vapor settles on the photo-sensitive islands and gives the mosaic better response toward the blue end of the visible spectrum.

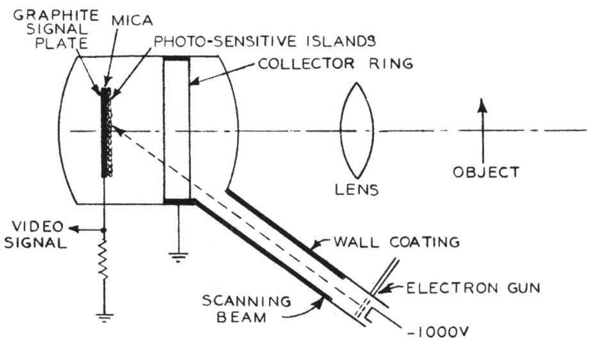

Figure 3-63 - Iconoscope Pick-up Tube

The iconoscope is a storage-type device in which the varying illumination of an optical image on the mosaic causes emission from the photo-sensitive islands. The charge on each picture element represented by the photo-sensitive element remains constant until released by the scanning beam. The operation of the iconoscope is best understood by considering first the action resulting from scanning the mosaic in darkness, *i.e.*, with no optical image or light on the mosaic.

With the collector ring grounded and the cathode potential fixed at -1000 volts, the beam acquires a kinetic energy of 1000 electron volts by the time it reaches the mosaic. On striking the mosaic, the beam causes secondary emission of electrons from the photosensitive islands, *i.e.*, each beam electron knocks several secondary electrons off the photosensitive island. The ratio of secondaries to beam electrons is 6:1 under dark conditions. The secondary electrons, for the most part, rain back on the mosaic. Enough secondaries travel to the collector ring for the collector-ring current to be equal to the beam current (since the mosaic is completely insulated, the current leaving it must equal the current arriving in the scanning beam)

Figuratively speaking, the scanning beam plows along the mosaic, causing an eruption of secondary electrons from the photo-sensitive surface. The element under the scanning beam charges up to about 2 volts, due to loss of electrons. This value represents the maximum charge which the element can attain by secondary emission and is known as the white level. As the scanning beam moves across the mosaic, part of the electron shower can fall back on the scanned area and reduce the positive charge on picture elements just scanned. At the right-hand edge of the mosaic, however, the scanning beam is turned off for retrace, and no more secondaries are generated to discharge the last part of the trace. Similarly, the beam is cut off at the bottom of the mosaic for vertical retrace; therefore, the last few scanning lines do not receive a proportionate share of the electron rain and remain partially charged. Remember that this action is occurring in complete darkness.

As the electron beam starts scanning the second frame, it encounters elements of the mosaic on the right-hand side and on the bottom that are partially charged, due to the loss of electrons. These elements appear as though they had been exposed to white light. When the beam scans them, fewer secondaries are emitted, and a signal voltage is impressed on the signal plate. This voltage has the waveshape shown in Figure 3-64 vertical and horizontal scans. It is an unwanted signal, that is due to uneven redistribution of secondary electrons, and it is called a shading signal. For eliminating shading signals, equal-amplitude opposite-phase signals are fed

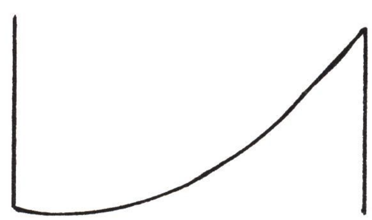

Figure 3-64 - Shading Signal Waveshape

into an amplifier stage following the pick-up tube. The unwanted signal may, fortunately, be effected by a combination of parabolic and saw-tooth signals which can be generated quite easily.

Now we may consider the action of the scanning beam when the mosaic is illuminated by a scene. Bright areas in the scene cause the islands to emit electrons. These electrons travel to the collector ring or redistribute themselves over the mosaic. Suppose a gray tone causes a photo-sensitive island to charge up to +1.5 volts. Then, when the scanning beam comes along, this particular element can only be charged by a differential of 0.5 volt to the white level. On the other hand, a black area leaves the element discharged until it is scanned, at which time the element can charge to the full 2-volt white level. The video signal current in the load resistor is shown in Figure 3-65.

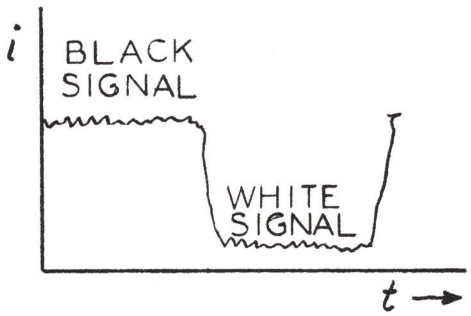

Figure 3-65 - Video Signal for Illuminated Scene

In Figure 3-63 the electron gun for the iconoscope is shown at an angle with the mosaic. This geometrical arrangement produces an effect known as keystoning. For a given angle of deflection of the scanning beam, more of the mosaic top is scanned than the bottom. If no correction were applied to the horizontal scanning generator, the resultant pattern on a monitor would appear as shown in Figure 3-66.

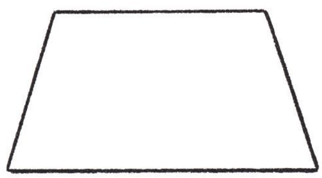

Figure 3-66 - Keystone Pattern

To correct for keystoning, the horizontal scanning generator is modulated by a 60-cycle sawtooth that increases the horizontal scanning current peak-to-peak value linearly at a 60-cycle rate, so that the angle of deflection becomes larger as the beam is deflected vertically.

IMAGE ORTHICON PICK-UP TUBE - The image orthicon is at least 100 times more sensitive than the iconoscope. Also, it is free from the annoying shading and edge-flare effects of the iconoscope. It will deliver a satisfactory picture, without readjustment, when the scene brightness changes by a factor of 100 to 1. A satisfactory picture may be obtained when the incident light on the scene is only 10 foot-candles. The sensitivity of the image orthicon makes it an ideal tube for pick-up of outdoor events.

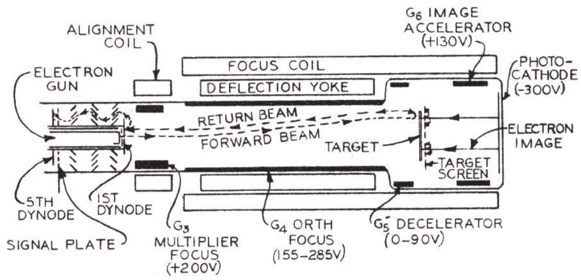

Figure 3-67 - Image Orthicon Pick-up Tube

A sketch of the image orthicon tube construction is shown in Figure 3-67. The tube contains an electron gun with a grid for controlling the current in the scanning beam. The #3 grid, sometimes called the "persuader", causes electrons from the first dynode to go to the second dynode. The #4 grid, which is the coating on the tube wall, together with the magnetic focusing field, focuses the electron beam on the target. The decelerating ring, grid #5, produces an electric field which improves corner focus.

The target is a special glass membrane stretched in a metal ring. The thickness of the glass is approximately 0.0001 inch. On the image side of the target, and at a distance of 0.001 inch, is a mesh screen having 250,000 holes per square inch.

Grid #6 is a ring placed between the target and photocathode. It aids the focusing of electrons from the photocathode on the target.

The photocathode is a transparent layer of cesium in type 2P23 tubes, antimony in type 5769 tubes, and bismuth in type C73150 tubes. The cesium tubes have high infra-red response, while the antimony and bismuth tubes have a more uniform color response in the blue regions.

IMAGE ORTHICON OPERATION - When an optical image is focused on the photocathode, electrons are emitted in proportion to the light and dark areas of the scene. Since the photocathode is at a potential of about -300 volts with respect to the ground and the target screen, the electrons are accelerated toward the target. The action of the focusing coil and the #6 grid focuses the electrons on the target. Thus the optical image is converted into an electron image which bombards the target.

Bombardment of the target causes an emission of the electrons from the glass. Secondary electrons released by the target are collected by the screen. Secondary emission leaves a positive charge pattern on the front of the target, corresponding to the electron image.

Because of the thinness of the glass target, it does not matter, for the electron beam, on which side of the glass the positive charge lies. Upon its arrival near the target rear surface, the beam deposits enough electrons to neutralize the charge. The remainder of the beam turns around and heads toward the rear of the tube. During frame time, the deposited electrons flow through the glass and unite with the positive charge.

The returning electron beam is equal to the electrons emitted by the cathode (nearly a constant number) minus those electrons deposited on the target. The returning beam, therefore, is the original beam modulated by the video signal.

An electron multiplier is located at the rear of the tube. The construction of this multiplier is shown in Figure 3-68.

It is such as to offer an almost opaque surface to the electrons entering from the front. Electrons leaving each dynode, however, find negligible resistance to their travel.

The return beam containing the video information strikes the first dynode, causing secondary emission. The secondary electrons are persuaded to the second dynode by the action of the "persuader," or multiplier focus electrode. As the beam travels from dynode to dynode, the original return beam is multiplied by secondary emission. The final signal is removed from the signal plate. The overall gain in the electron multiplier can be as high as 2000.

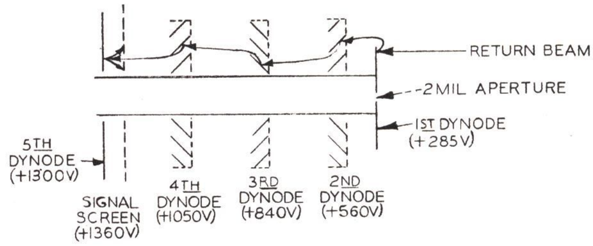

Figure 3-68 - Electron Multiplier for Image Orthicon

In tube manufacture, the electron gun may become tilted with respect to the tube axis. Electrons emitted from such a gun would enter the focus field with a transverse component of velocity. A force would be developed, which would cause the beam to travel in a radius about the tube axis. The net effect is a spiraling of the beam down the tube. To correct for misalignment of the electron gun, an alignment coil is placed just in front of the gun. It produces a transverse field which cancels the deflection of the beam due to gun tilt.

TELEVISION TECHNICAL TRAINING PROGRAM

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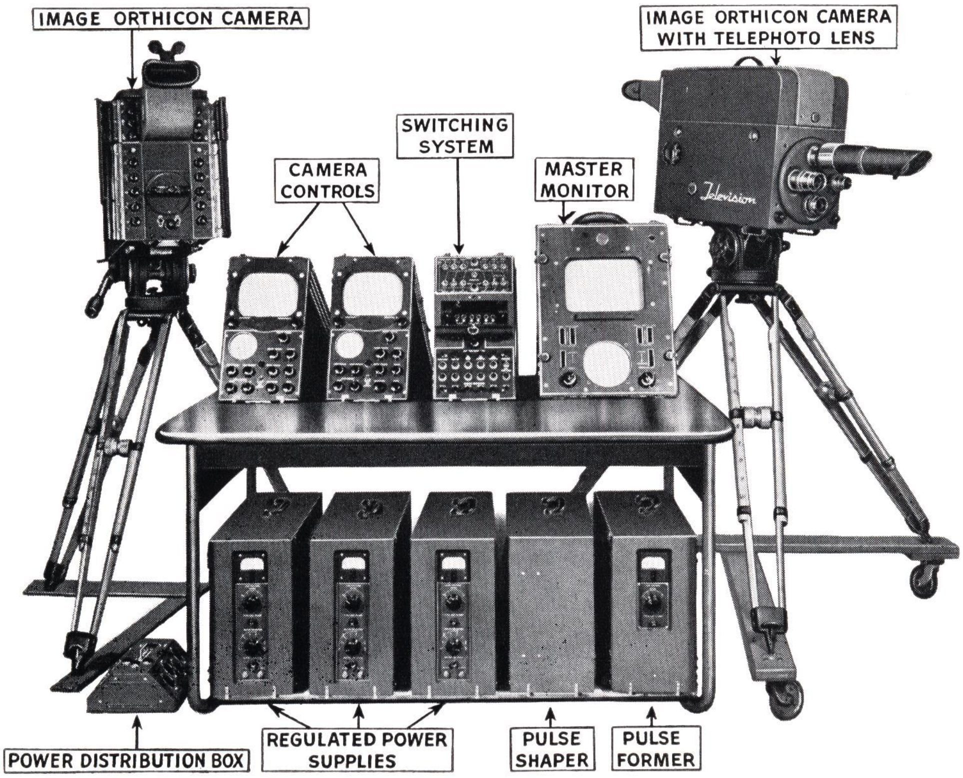
SECTION IV

TERMINAL EQUIPMENT SPECIFICATIONS

RCA Television Field Pick-up Equipment



The RCA Television Field Pickup Equipment is designed for portable or field use in picking up television programs such as sporting events, parades, outdoor or indoor shows, and other special events in places where permanent television installations are not available. The design of the equipment is centered around the RCA Image Orthicon camera tube which is so sensitive that it may be used with incident illumination on the scene as low as approximately one foot candle, and which is entirely free of any blocking or "charging-up" effect from flashes of excess light which paralyze other types of pick-up tubes.

The Field Equipment includes such important features as a four-position lens turret on each camera, an electronic view finder in each camera, a complete telephone intercommunication system, accessibility of tubes, components, and circuits for easy servicing, and many other features.

To facilitate portability, the equipment has been divided into relatively small units with emphasis placed on keeping the number of major pieces to a minimum, and at the same time maintaining high standards of reliability and flexibility in operation. Wherever possible the major units have the shape and approximate size of a medium sized suitcase. The camera and view finder, master monitor, and power distribution box are the only exceptions. Each unit is provided with one or more carrying handles, and covers and shock mounts to protect fragile parts during transportation. All interconnections are made with cables and plugs which may be connected or disconnected in a few minutes.

A general practice of making all electrical connections through receptacles mounted on the rear panels of the suitcase units has been followed. An exception exists in the case of intercommunication head-sets which are plugged into jacks on the front of the Field Switching System. Whenever possible, multiple conductor cables are used so that the number of cable connections is kept to a minimum consistent with flexibility of the equipment. With few exceptions, the connectors used have single-turn locking rings which prevent accidental disconnecting of the cables.

Careful consideration has been given to conservative design in the selection of high quality components and in allowing ample reserve in ratings. Also attention has been given to providing rugged construction and secure mountings so that the equipment will stand the wear and tear of daily use over long periods of time.

The Field Equipment is so designed that it may be set up for temporary operation on a table or desk. A special Field Control Desk (MI-26960) is available if it is desired to make a semi-permanent installation of this equipment for studio use. In such a case, the desk and control units comprise a simple operating console. The equipment may also be used in conjunction with a mobile television unit in which the suitcases may be installed to form a mobile television studio.

The units included with the standard Two-Camera Chain, Field Pick-Up Equipment are as follows:

2—Type TK-30A Field Camera Equipments
1—Type TG-10A Field Synchronizing Generator
1—Type TS 30A Field Switching Equipment
(All equipments are supplied with tubes)

The Type TK-30A Field Camera Equipment includes:

1—High Sensitivity Image Orthicon Camera with newsreel-type tripod, plug-in electronic view finder employing a 5″ Kinescope and three turret-mounted lenses (50 mm and 90 mm and 135 mm focal lengths).

1—Field Camera Control Unit. This unit provides the required control and operating voltages for the Field Camera and provides picture (on a 7″ Kinescope) and wave form (on a 3″ Cathode Ray Oscilloscope tube) monitoring of the camera signal.

1—Field type Power Supply. This unit contains the heater and plate supply transformer, rectifiers and plate-voltage regulating circuits.

1—Set of Camera-Camera Control Unit Cables; one 50′ length, one 100′ length and one 200′ length.

The Type TG-10A Field Synchronizing Generator includes:

1—Field Pulse Former
1—Field Pulse Shaper
1—Power Distribution Box. This unit provides for power supply connections to a-c power systems of three types: 3 phase—4 wire; Single phase—3 wire; Single phase—2 wire. 9 Twist Lok power outlets and 4 convenience outlets are provided.

The Type TS-30A Field Switching Equipment includes:

1—Switching System. This unit provides all the video program, monitor and intercommunication switching required for field pick-up equipment using up to four cameras, plus two auxiliary video program lines. Camera, view finder, camera control and switching equipment tally lights indicate to performers, cameraman, control operators and program director which camera is supplying program.

The Field Type Master Monitor (listed below) can be switched to:

a. The outgoing video signal.

b. Relay equipment monitoring signal.

c. Either of the two auxiliary video program lines.

d. A separate Monitor input.

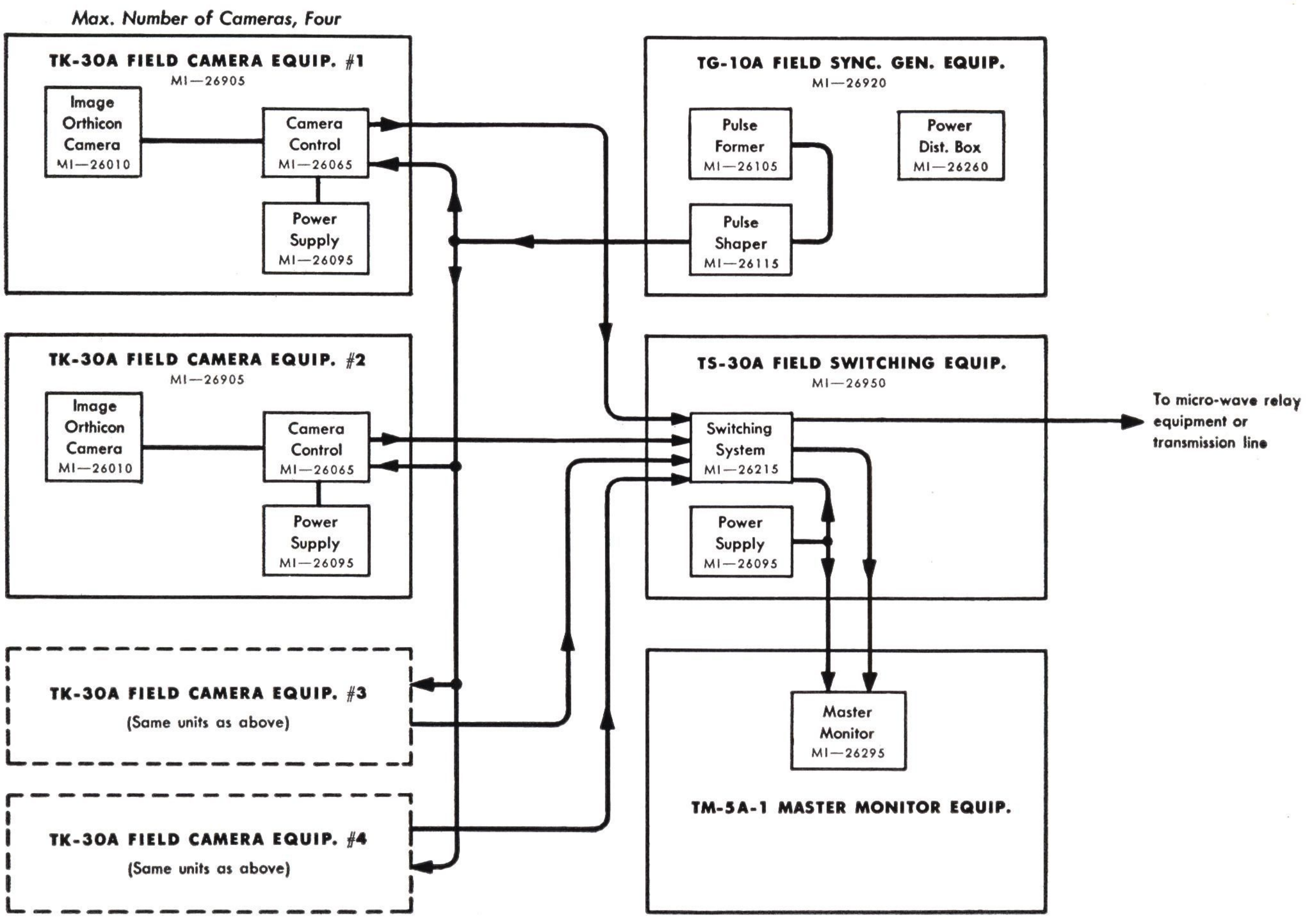
The audio intercommunication facilities provide a flexible set-up so that the program director can talk to any or all of the operating personnel and the home station, or various special and separate intercommunication circuits may be set up. All operating personnel normally hear program sound on one headphone, and intercommunication sound on the other.

1—Field Type Power Supply. This furnishes power to the switching system and Master Monitor.

OPTIONAL

1—Field Type Master Monitor. This unit provides for picture (on a 10″ Kinescope) and wave form (on a 5″ CRO Tube) monitoring of the Signal selected by the field switching system.

RCA TELEVISION FIELD PICKUP EQUIPMENT



PRINTED IN U.S.A.

Field Television Camera Type TK-30A

Features

- Highly sensitive at extremely low light levels.
- Able to handle enormous light ranges.
- No loss of picture after intense flashes of light.
- Simplified interconnections providing quick assembly on location.
- Electronic view finder.
- Rugged mechanical construction.
- A four position lens turret controlled from rear.
- Provision for two intercom telephone sets.
- Suitable for studio use.
- Easy access to all parts.

Uses

The TK-30 television camera is intended to be used in field television pick-ups of all kinds. It is especially suitable for use where the lighting conditions are poor, as is frequently the case at sporting events, in night clubs, and at other remote pick-up points. While designed especially for field use, it is also satisfactory for most types of studio programs; and for many applications the TK-30A has special advantages.

Description

The TK-30A is a portable, field television camera equipment consisting of camera, tripod, camera cntrol, field power supply, and miscellaneous accessory items; such as: cables, etc. The camera makes use of the RCA-developed Image Orthicon. The remarkable sensitivity of the Image Orthicon is so great that operation is possible with light levels as low as one foot-candle with an f 3.5 lens. This is a considerable improvement over other types of picture tubes, and makes possible field television pick-ups without elaborate, special lighting installations, and under conditions which hitherto would have been impossible. In addition, the Image Orthicon is able to adapt itself automatically to enormous changes in scene brilliance without serious loss of contrast anywhere in the range. This characteristic makes it possible to shift instantly from a dark scene in heavy shadows to another in bright sunlight with only very slight readjustment. The Image Orthicon is able to withstand extreme peaks of intense illumination, such as photo flash lamps aimed directly at the lens, without any after effects requiring the resetting of controls.

The Field Camera Control is contained in a small easily-carried case. On the front, there are located two cathode ray tubes which serve as indicators of the picture quality. A seven inch kinescope is used as a picture monitor, and a three inch oscilloscope is used as a wave form monitor.

The picture signal amplifier performs the following several important functions:

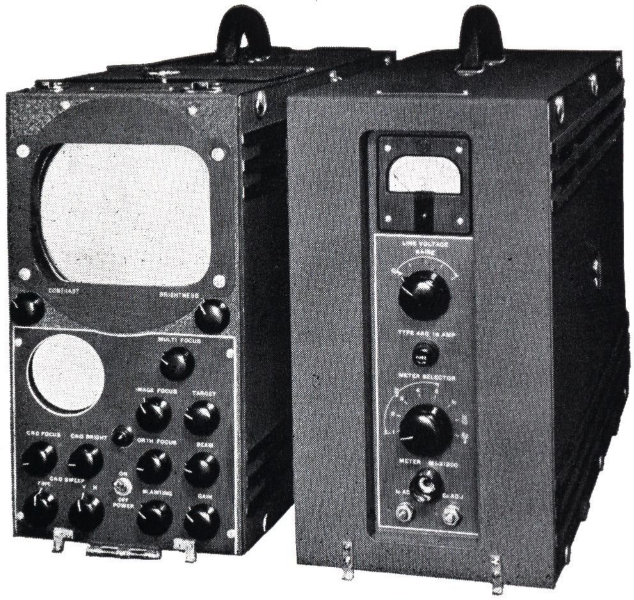
1. It provides a gain control for the picture signal.
2. It mixes the Picture Blanking signal with the signal from the Camera.
3. It establishes black level at the beginning of each scanning line by means of a "clamp" circuit.
4. It provides for the addition of the Synchronizing signal whenever only a single camera chain is used.
5. Its output stage is a line amplifier capable of delivering two volts peak to peak composite picture and synchronizing signal to a 75 ohm coaxial transmission line (or 1.5 volts of picture only).
6. It includes a stage for introducing a fixed amount of gamma correction.
7. It includes high level driver stages for feeding the two monitor tubes.

The Field Power Supply is a portable unit designed to provide all the d-c required by the circuits in the Field Camera, Field View Finder, and Field Camera Control in one camera chain. It may, of course, be used for any other application where its voltage and current ratings meet the requirements. The output voltage of this power supply is electronically regulated within very close limits. It is capable of delivering 1 ampere at a maximum of 285 volts. The internal impedance of the power supply is less than 0.25 ohm. This low impedance makes it an excellent power supply for amplifiers having variable current requirements and critical low frequency response such as television amplifiers.

A separate electronic regulator circuit is provided to hold a constant current flow regardless of resistance changes, through the focusing field coil in the Field Camera.

On the rear panel are two receptacles for a-c input and power output respectively. In addition there is included a single convenience outlet with fuse.

The complete camera may be disassembled into several parts for easy carrying. The camera is built into an exceedingly compact case which mounts on top of the tripod. All controls are conveniently located on the back. The camera assembly includes a picture signal preamplifier and the deflection and camera blanking circuits. A feature of this camera is the provision of a lens turret in which four lenses of different focal lengths may be mounted. On the rear of the case is located a large handle which rotates the lens turret. A trigger switch incorporated in the handle cuts off the picture during the interval while the handle is turning. Changing from one lens to another requires only one and a half seconds. This compares to two or three minutes with prior types of cameras. Because the plate of the Image Orthicon is much smaller than that of previously designed pickup tubes, the focal lengths of the lenses required are only about half as great. This makes it possible to use relatively inexpensive standard lenses for all types of pick-up.



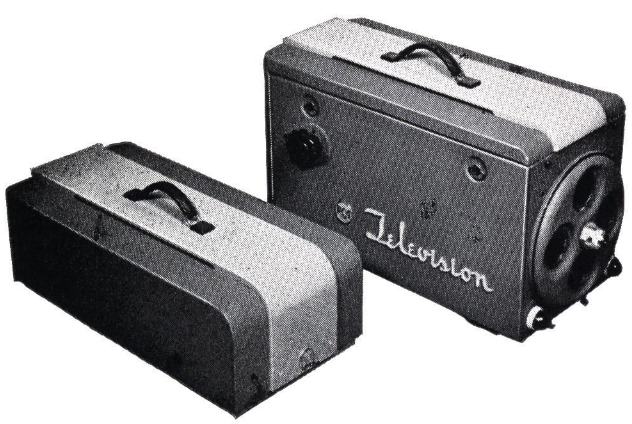
Field Camera Control and Field Power Supply

The operator focuses the picture by observing the image in the electronic view finder, constituting the upper section of the camera assembly, and adjusting a knob on the right side of the cabinet. This knob slides the Orthicon back and forth inside the case. This saves having to adjust the lenses themselves for focusing. The use of the electronic view finder with this camera is a necessity; since at low light levels an optical view finder would not be satisfactory. It also has the advantage of eliminating the need for additional lenses which would be required for an optical system. The view finder employs a five inch kinescope with sufficient brilliance to produce a satisfactory picture under normal outdoor light conditions. Since the operator sees on the face of this kinescope the picture which is being transmitted, he is able to focus the picture, and also to monitor the quality and general operation. Two different viewing hoods are provided: one straight-on type, and the other a periscope type, which may be mounted in either of two positions. This gives the operator a choice of three different viewing heights. For ease in transporting and maintenance, the view finder and camera are separate units, each of which is an integral unit in itself. A streamlined cover with a carrying handle is placed on the camera unit when the view finder is removed. It is also possible to operate the camera without the view finder: as for instance where the camera is set up in a fixed position and operates unattended.

Specifications

FIELD CAMERA, CONTROL & POWER SUPPLY

Number of Scanning Lines ____ 525



TK-30A Electronic View Finder and Camera disassembled for easy carrying

Interlacing ____ 2 to 1
Field Repetition Rate ____ 60 per sec.
Frame Repetition Rate ____ 30 per sec.
Line Repetition Rate ____ 15750 per sec.
Picture Signal Level ____ 2.0 volts, peak-to-peak, max. of which 75% is picture and blank, and 25% is sinc. (See RMA Standards).
Picture Signal Polarity at Output ____ Black negative
Type of Transmission Line for Picture Signal ____ Coaxial
Impedance of Transmission Line ____ 75 ohms
Maximum Length of Camera Cable ____ 1000 ft.
Total Included Angle of Lenses (in horizontal plane):
- a. 50 mm f1.9 Ektar ____ 34°
- b. 90 mm f3.5 Ektar ____ 20°
- c. 135 mm f3.8 Ektar ____ 13°
- ***d. 8.5 in., f3.9 Ilex ____ 8°
- ***e. 13 in., f3.5 Ilex ____ 5.3°
- ***f. 15 in. ____ 4.5°
- ***g. 17 in. ____ 4°
- ***h. 25 in. ____ 2.75°

Incident Illumination on Scene:
- (a) Minimum (approx.) ____ 0.5 ft. candle
- (b) Required for First Grade Results ____ 10 to 20 ft. candles
- (c) Maximum ____ Bright sunlight

Note: Figure for (a) above is based on the use of an f3.5 lens or faster.

Primary Volts ____ 98-129 volts, a-c, 50-60 cycles
Primary Voltage Taps:

	Nominal	*Range*
Tap No. 1	125 v.	121-129 v.
Tap No. 2	117 v.	113-121 v.
Tap No. 3	109 v.	105-113 v.
Tap No. 4	102 v.	98-106 v.

A-c Power Input for All Units ____ Approx. 1200 watts

Power Output of Supply:
- Regulated d-c Supply 270-285 volts ____ 1 amp.
- Constant Current Supply intended to operate into 2000 ohm load (focusing coil) ____ 50-80 ma.

Dimensions (in inches):

FIELD CAMERA

CASE ONLY			OVERALL		
Length	*Width*	*Height*	*Length*	*Width*	*Height*
20⅛	10⅜	$11\frac{3}{16}$	26	11¾	13⅝**

VIEW FINDER

CASE ONLY			OVERALL		
Length	*Width*	*Height*	*Length*	*Width*	*Height*
21¾	10⅜	7	21¾‡	11¾	13⅝**

FIELD CAMERA CONTROL

CASE ONLY			OVERALL		
Length	*Width*	*Height*	*Length*	*Width*	*Height*
24½	8⅛	15⅛	27¼	8½	18½

FIELD POWER SUPPLY

CASE ONLY			OVERALL		
Length	*Width*	*Height*	*Length*	*Width*	*Height*
24½	8⅛	15⅛	24½	8½	18½

Camera Cable Dimensions:
- Diameter ____ 0.840 in.
- Standard Lengths ____ 50 ft., 100 ft., 200 ft.

Weights:
- Field Camera (less Lenses) ____ 65 lbs.
- View Finder (less Hood) ____ 34 lbs.
- Field Camera Control ____ 65 lbs.
- Field Power Supply ____ 58 lbs.
- Turret with 3 Ektar Lenses ____ 4¾ lbs.
- Camera Cable (200 ft. with plugs) ____ 80 lbs.

Finish ____ Two tone umber gray wrinkle with chrome trim

Stock Identification:
- Field Camera ____ MI-26010
- View Finder ____ MI-26015
- Field Camera Tripod ____ MI-26045
- Field Camera Control ____ MI-26065
- Field Power Supply ____ MI-26095

‡ Less viewing hood.
* Less lenses.
** Including cover.
*** Not standard equipment. Available as accessory items.

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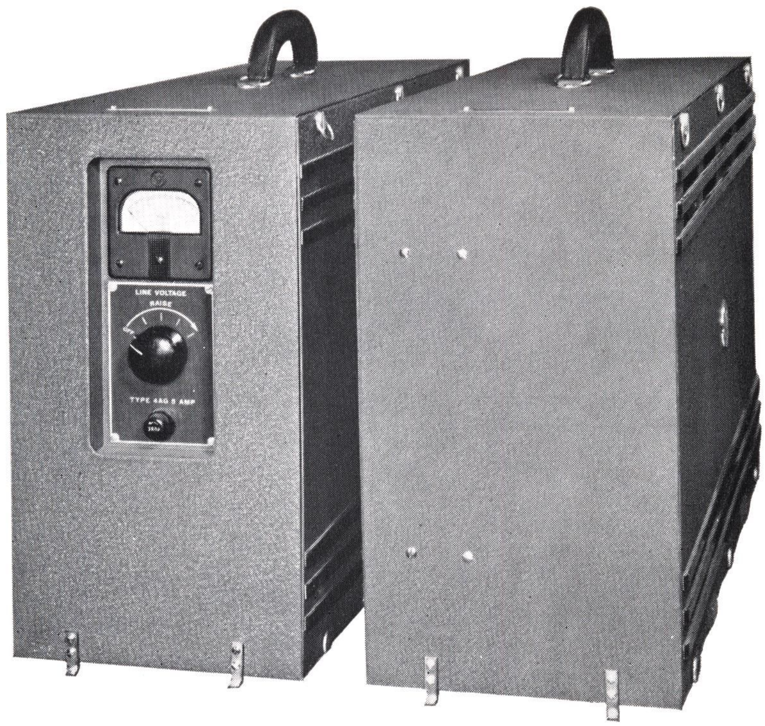
Field Synchronizing Generator Type TG-10A



Features

- Delivers standard RMA synchronizing and blanking.
- Also delivers separate horizontal and vertical driving signals.
- Complete in two suitcases, Pulse Former and Pulse Shaper.
- Frequency stabilization either by 60 cycle power line or by quartz crystal.
- Built-in cathode ray tube indicator for counter circuits.
- Built-in regulated power supply.
- Single cable connection between the two suitcases.
- All output signals, except synchronizing, on single cable.
- Synchronizing on separate cable to provide for single or multiple camera operation.
- Operation over wide range of line voltage.
- Built-in line voltage meter and tap switch.
- Convenience outlet with fuse.

Uses

The field synchronizing generator is the heart of the field television pickup equipment. Its function is to provide all the timing information, in the form of electrical pulse signals, required for controlling and synchronizing the scanning processes in both the field pickup equipment and the home receivers.

Description

In order to keep the weight and size of the TG-10A within reasonable limits, the equipment has been divided into two parts, each contained in a separate case, and called the Field Pulse Former and the Field Pulse Shaper. Also included with the TG-10A is a Power Distribution Box which is intended to be used for connecting the 117 volt power source to the various units of the RCA Field Television Equipment.

The equipment generates four separate signals which are used in various ways to produce the RMA standard television signal. These four signals are those required for a 525 line interlaced system as recommended by the RMA. The signals are usually designated as follows:

1. Synchronizing
2. Picture blanking
3. Vertical driving (at field frequency, 60 cycles)
4. Horizontal driving (at line frequency, 15,750 cycles)

The first two of these signals, Synchronizing and Picture Blanking, are used directly in composing the final picture signal fed to the output of the system. In other words, they appear as parts of the composite picture signal. The last two signals, Horizontal and Vertical Driving, are used in the pickup equipment only. Their principal function is to trigger deflection generators in cameras and monitors. They are also used for keying signals in "clamp" circuits and for blanking signals in the camera.

FIELD PULSE FORMER

The Field Pulse Former contains the timing circuits required in the system. Specifically, they include the master oscillator which operates at twice line frequency (31,500 cycles), a series of counters for stepping this master frequency down to line frequency (15,750 cycles) and to field frequency (60 cycles), and an automatic frequency control circuit for locking the synchronizing generator to the power supply frequency. A crystal oscillator operating at 94.5 kc. is provided as an alternative means of stabilizing the generator where the power supply system is not stable enough to serve as a reference.

Controls for the counter circuits, AFC circuit, and crystal oscillator are made accessible by removing the side cover on

Power Distribution Box

the tube side of the unit. A cathode ray tube indicator (RCA 2BP1) for the counter circuits is mounted within the case and is visible when the cover is removed to make adjustments of the controls.

A single cable containing 4 coaxial lines and several other conductors carries signals and power between the Field Pulse Former and the Field Pulse Shaper. The a-c power enters the Pulse Former through a special connector. A convenience outlet, separately fused for 10 amperes, is provided on the rear panel. No other connections to this unit are required.

The Field Pulse Former also includes a regulated power supply which provides all the plate current required by both the Former and the Shaper. The Transformer primary is tapped at several points to accommodate a wide range of line voltage (98 to 129 volts). A selector switch for these taps is mounted on the front panel directly under a line voltmeter which indicates when the proper tap has been selected.

FIELD PULSE SHAPER

The Field Pulse Shaper contains all circuits necessary for shaping, mixing, and pulse width control to produce the four output signals. Pulse widths are adjustable by means of screwdriver-type controls which may be locked in position.

The outputs are fed to 75 ohm coaxial lines from the plate circuits of the final amplifier tubes (RCA 6AG7). These outputs are coupled through blocking capacitors to prevent d-c from flowing in the transmission lines. The normal signal level on these lines is 4 volts, peak to peak. All four signals are negative in polarity.

Two separate cables carry the signals to other units in the system. One multiple cable, consisting of several coaxials, carries the Picture Blanking and the Horizontal and Vertical Driving signals to the Field Camera Controls. The second cable is a single coaxial line which carries the Synchronizing signal.

Two filament transformers are mounted in this unit to supply the tube heaters. Plate current for the tubes is provided by the regulated power supply in the Field Pulse Former.

POWER DISTRIBUTION BOX

This distribution box has nine 2-prong twistlock receptacles which fit the power cables supplied with the equipment. This number of outlets is more than sufficient for a four camera setup, and thus allows extra outlets for operation of associated audio equipment. Two standard convenience outlets are also provided for soldering irons, trouble lights, etc.

The power-feed line to the box is a four-conductor water proof cable (each conductor #10 gauge, stranded) connected through 4-prong twistlock connectors. A total of 200 feet of this cable is supplied with each equipment.

Provision is made for connecting this box to any one of three types of power distribution lines which are normally encountered in the United States. These are:

1. Single phase, 2 wire (117 volts).
2. Single phase, 3 wire (117 volts from each outer line to neutral).
3. Three phase, 4 wire (117 volts from each outer line to neutral).

A link board under a trap door at one end of the box provides easy means for rearranging the circuits to fit any of these three systems. Outlets are color-coded to indicate phasing on the three phase system, and correspondingly colored pilot lamps indicate which phases are "hot" in case a main fuse burns out.

Provision is thus made to utilize all elements of any available power distribution system so as to minimize voltage drop.

Specifications

Field Repetition Rate—60 per sec.
Frame Repetition Rate—30 per sec.
Line Repetition Rate—15,750 per sec.
Synchronizing Generator Master Oscillator Frequency 31,500 cycles/sec.

Synchronizing Generator Counter Ratios:
- First—7 : 1
- Second—5 : 1
- Third—5 : 1
- Fourth—3 : 1

Frequency Stability of Horizontal Sync. (when stabilized by power supply)— ±0.15%/sec. max.

Frequency of Quartz Crystal—94,500 cycles/sec. ±50 cycles

Synchronizing Generator Output Signals:
- (a) Signal Level (all signals) 4.0 (—0.5, +1.0 volts, peak-to-peak)
- (b) Signal Polarity (all signals)—Negative
- (c) Waveform-Sync.—Defined by "Recomended Sync. Generator Waveforms", a drawing submimtted January 22, 1946 (Revised October 9, 1946) by the RMA Sub-committee on Studio Facilities.
- (d) Waveform-Picture Blanking—Defined by "Recommended Sync. Generator Waveforms", a drawing submitted January 22, 1946 (Revised October 9, 1946) by the RMA Sub-committee on Studio Facilities.
- (e) Waveform-Horizontal Driving—Rectangular pulse, 15,750/sec. Width 6.3 microsec. (approx.)
- (f) Waveform-Vertical Driving—Rectangular pulse, 60/sec. Width 4% or .00067 sec.

A-c Power Input, Sync Gen.—325 watts

Dimensions (in inches):

CASE ONLY Length	Width	Height	OVERALL Length	Width	Height
FIELD PULSE FORMER					
24½	8⅛	15⅛	25¾	8½	18½
FIELD PULSE SHAPER					
24½	8⅛	15⅛	25¾	8½	18½
POWER DISTRIBUTION BOX					
11⅛	8⅞	3¾	11⅜	8⅞	5

Weights:
- Field Pulse Former—67½ lbs.
- Field Pulse Shaper—52 lbs.
- Power Distribution Box—10 lbs.

Finish—Two tone umber gray wrinkle with chrome trim

Stock Identification:
- Field Pulse Former—MI-26105
- Field Pulse Shaper—MI-26115
- Power Distribution Box—MI-26260

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Master Monitor Type TM-5A

Features

- Operates with composite picture signal input (synchronized operation) or with separate picture signal and pulse signal input voltages (driven operation).
- Special 10 inch diameter, kinescope with aluminum backing makes possible a very brilliant picture.
- Special low capacity input connection.
- Compact design permits location in operating consoles with minimum space requirements. Operator can easily look over the top of the console and can observe at least three adjacent monitors without difficulty.
- Synchronization of the oscilloscope sweep with the kinescope sweep at half line or half field frequency is completely automatic.
- Operating controls are extremely simple.
- Pulse high voltage supply reduces shock hazard considerably.
- Tubes and circuits are readily accessible.
- Adapter is available for rack mounting and a suitcase type enclosure available for portable or field use.
- Calibration circuit permits quick reference to a fixed voltage level.
- Grid circuit of oscilloscope is available for pulse measuring techniques.

Uses

The Type TM-5A Master Monitor provides in a compact chassis a complete monitoring unit adaptable to the supervision of composite picture signals at any stage of transmission, from camera pickup to radio transmitter input. It may be used for both picture and waveform monitoring of signals from the relay receiver, the output signal at the master control room, or any other picture signals it may be desirable to monitor at the radio transmitter location.

Description

The Master Monitor is furnished in chassis form. It may, therefore, be placed in a housing and grouped with other master monitors or camera controls to form an operating console. A case for table top mounting is available so it can be used conveniently with field equipment for monitoring purposes, and in conjunction with the adaptor, MI-26526, it can be used as a rack mounted monitor.

The unit employs a 10 inch kinescope for direct picture monitoring and a 5 inch oscilloscope for signal component analysis. Input circuits are arranged to permit the same or different picture signals to appear on the kinescope and oscilloscope screens at the same time.

A calibration circuit is included to establish a definite voltage level on the oscilloscope screen for measuring purposes. The horizontal scanning frequency of the oscilloscope tube is automatically half that of the kinescope and results in two cycles of either horizontal or vertical pulses, as may be selected by the operator, appearing on the oscilloscope screen.

The vertical front panel of the monitor, finished in dark umber gray is arranged with an opening at the top center, fitted with a rectangular mask, for the 10 inch kinescope to present the picture screen. The screen of the 5 inch oscilloscope is arranged immediately below the kinescope screen in a 5 inch circular opening. The lower section of the panel carries the switches and controls, conveniently grouped.

With the ends of the kinescope and oscilloscope presented to the panel, the other components of the circuits are mounted on vertical chassis on both sides of the cathode-ray tubes with tube sockets and circuit components arranged on narrow shelf members so that all parts are readily accessible for servicing.

A twelve contact plug at the rear of the assembly provides for the connection of necessary input power and external synchronizing pulse wiring. A safety feature is included in the form of an interlock which is attached to the monitor, so that withdrawal of the chassis from the case opens the high voltage circuits in the unit to prevent accidental contact with dangerous potentials.

The Master Monitor may be operated as either a "synchronized" or as a "driven" monitor. In the synchronized case, the scanning circuits are operated by blocking oscillators which in turn are triggered by the sync. pulses contained in the incoming composite picture signal. In the driven case, the incoming signal will normally come from a camera chain without sync. pulses. The scanning circuits are therefore "driven" directly by separate signals from the synchronizing generator. Connections to the sync. generator are made through the multi-contact plug. The switching arrangement employed for selecting the type of operation cuts off the blocking oscillators by opening the cathode circuits when the unit is operated as a driven monitor. The unit includes three step down transformers to furnish current for the tube heaters and filaments but d-c currents for the tube plate circuits and centering circuits must be obtained from an external regulated power supply.

Specifications

INPUT POWER WHEN USED AS LINE OR RELAY RECEIVER MONITOR

From Line for Tube Heaters:
- Line Voltage — 105-125 volts
- Line Frequency — 50-60 cycles, single phase

From Power Supply:
- Plate Voltage — 285 volts d-c
- Plate Current — 510 ma.
- Centering Voltage — —7 volts d-c

INPUT FROM CAMERA CHAIN WHEN USED AS CAMERA OR PROGRAM MONITOR

	Peak to Peak Voltage	*Frequency in Cycles*	*Pulse Width*
Vertical Drive	2 min.	60	4%
Horizontal Drive	2 min.	15,750	10%
*Oscillator Drive	8	Mixed 30 and 7875	
** Bias	—18	d-c	
*** Tally Light	6.3 v.		

Frequency Response:
- Kinescope Amplifier — Flat ±1 db to 8 mc.
- Oscilloscope Amplifier (Vertical Deflection) — Flat ±1.5 db to 4 mc.

Input Impedance:
- CRO Input — High
- Kinescope Input — High
- CRO Drive Signal — High

Signal Input Range:
- CRO Input — 0.5 to 3 volts
- Kinescope Input — 0.5 to 3 volts

Chassis Dimensions — 17¾" high; 13" wide; 20¼" deep

Weight — 68 lbs.

Stock Identification (chassis only) — MI-26135

* Use of this signal is optional.

** Used only with camera chain, under which condition following output voltages are available from monitor:
- Pedestal Control — 0 to —18 volts d-c
- Video Gain Control — 0 to —18 volts d-c

*** Connected to switching or monitor heater circuit.

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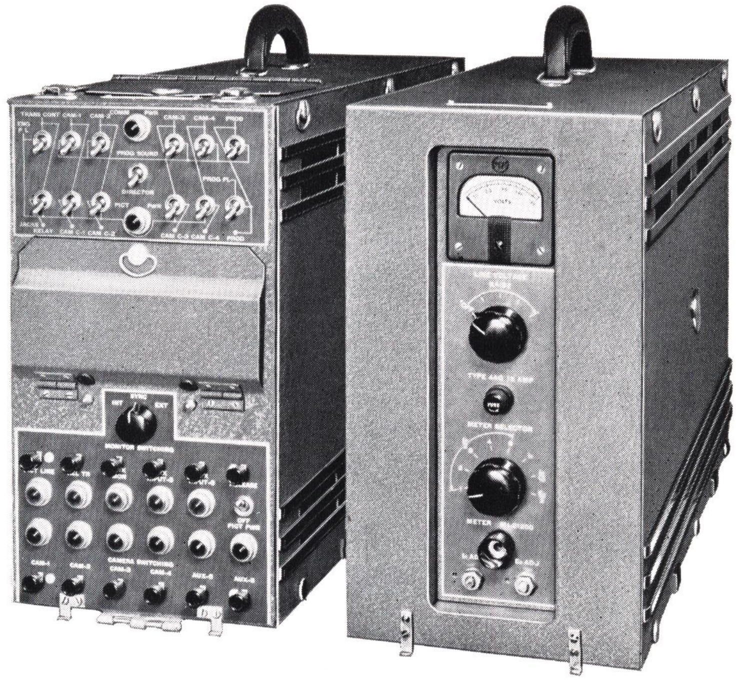
Field Switching System Type TS-30A



Features

- Surgeless camera switching (clamp circuit) for four cameras and two auxiliary signals.
- Switching between cameras without interrupting sync, thus eliminating frame slipping at receivers.
- Individual level control on each auxiliary picture input.
- Switching of Master Monitor for checking the outgoing picture line, auxiliary lines, relay transmitter, etc.
- Push button switches for picture signals.
- Tally system to indicate "on-the-air" to the camera control operator, camera man, and performers.
- Clamp circuit holds black level constant.
- Sync. level adjustable over wide range.
- Incoming signal may be with or without sync.
- Operation in conjunction with a Master Monitor from a single external power supply.
- Built-in power supply with separate control switch for the intercom. system.
- Complete miniature "central office" for an inter-communication system between all operators in a four camera setup and the program director, technical director, and main studio.

Uses

The Field Switching System, when used in combination with the Field Master Monitor, is the equivalent, in the Field Equipment, of the director's console in a studio. It provides two major services in a setup involving more than one camera. The first is, of course, a means of switching between cameras and of monitoring the outgoing signal. The second is the provision of an intercommunication center for the telephone system which enables all operating personnel to talk with each other.

Description

The complete equipment consists of the Field Switching unit, contained in a compact, easily carried case; and the associated Field Power Supply, likewise contained in a portable case.

The picture signal circuits provide for switching between four cameras and two incoming auxiliary lines, or in unusual cases, between six cameras. Communication circuits are limited to a maximum of four cameras.

Two sets of push button switches are provided for picture switching. One set, located at the bottom of the front panel, and marked "CAMERA SWITCHING," switches signal from any of four cameras or two auxilliary inputs to the outgoing line. The second set marked "MONITOR SWITCHING" provides for switching the Field Master Monitor to any of the following five positions:

1. Outgoing picture line.
2. Monitor output of relay transmitter.
3. Incoming auxiliary line 5.
4. Incoming auxiliary line 6.
5. Spare input to monitor.

Each push button has an associated tally. Camera switching tallies operate in conjunction with tallies in the Cameras and Camera Controls.

The picture amplifier includes a "clamp" circuit to eliminate switching transients and other low frequency disturbances which may have been added to the signal earlier in the system, and thus provides that smooth switching which adds much to program technique.

The three 75-ohm coaxial outputs from the outgoing line amplifier are as follows:

1. Picture Output (for feeding a relay transmitter or studio line).
2. Master Monitor Output.
3. Auxiliary Monitor Output.

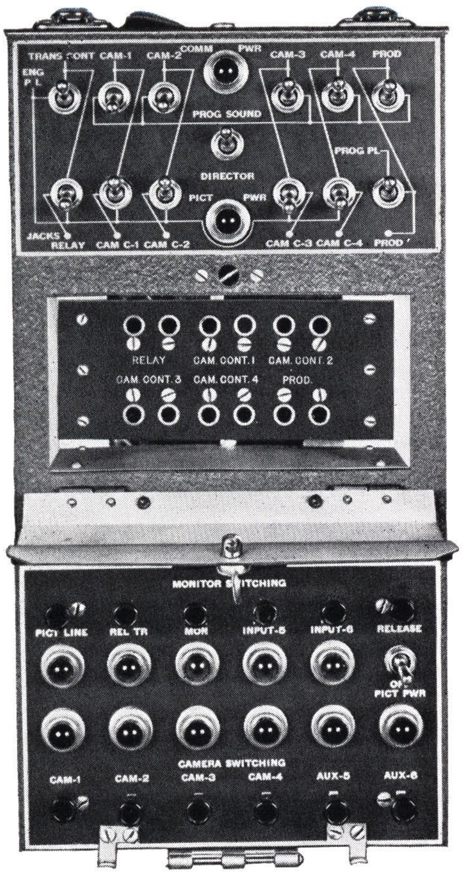
At output 1 appears the signal from the particular camera selected by the CAMERA SWITCHING push button. The second output is effectively in parallel with the first output.

The third output is provided to supply signal to any auxiliary equipment which it may be desired to operate such as an additional monitor, a standby link transmitter, or the switching system of an additional set of field equipment.

All three of these outputs deliver the same signal level and polarity, i.e., 2 volts, peak to peak, of picture and sync. with sync. negative. It is assumed that this level is based on the standard ratio of 75% picture and 25% sync. However, for signals from local Cameras, where sync. is mixed with the camera signal in the Field Switching System, the amount of synchronizing voltage may be increased above the 25% value by adjusting the Synchronizing Gain Control.

Pulse signals for operation of the clamp circuit are derived from the synchronizing signal. The clamp operates at black level so that the output stage always operates over the same portion of its characteristic.

Filament power for the picture and pulse amplifier tubes is supplied by a transformer in the Field Switching System. D-c for plate supply is obtained from an MI-26095 Field Power Supply which is also capable of providing plate current to a Field Master Monitor at the same time. The power control switch for the Field Power Supply with an associated tally, is located on the front panel of the Field Switching System.



Front view of Switching Unit showing panel detail

The intercommunication system provides talking circuits between the camera men, the camera control operator, the technical director, the program director, and any assistant production personnel who may be stationed near the cameras. It provides also a circuit for distribution of the program sound to all the operators of the system. Each operator may be provided with a telephone set consisting of a double ear phone head band and a microphone. One ear phone in each set reproduces the program sound, and the other reproduces the operators' conversation.

Recessed under the front panel of the Field Switching System is a jack board with accommodations for six telephone sets; one for each camera, one for the program director and one without program sound for the relay transmitter operator.

A group of toggle switches on the upper part of the front panel provides means for making several circuit combinations in the intercommunication system. The following combinations are available:

1. Separate circuit to each camera and the relay transmitter.
2. A common circuit to all cameras or any grouping of them.
3. Optional tie-in between operators and program director.
4. Optional tie-in between operators and the engineering PL. (Private Line).
5. Optional tie-in between engineering PL and production PL.
6. Optional circuit for the program director over the program line.

The circuit used for the intercommunication system is the common battery type. The power supply operates fom the a-c line and is contained in the Field Switching System. A separate power switch, fuse, and tally are provided so that the intercommunication system may be operated while the rest of the equipment is turned off.

Four separate cables carry the intercommunication and tally circuits between the Field Switching System and the four Field Camera Controls. A jack provides means for a 2 wire circuit to the relay transmitter. Receptacles are provided for connecting the program sound, and the engineering and program phone lines, or PL's, from the main studio or transmitter.

Controls normally used during show time are located on the front panel. Others, used rather infrequently, are located under a small trap door on top of the suitcase. Controls normally preset are located on the chassis and are made accessible by removing the cover on the tube side of the unit.

Individual coaxial connectors are provided for all incoming and outgoing picture and synchronizing lines. All other connections are made with multiple conductor cables to keep the number of connections to a minimum.

A removable front cover is provided to protect the switches and other controls from damage during transportation. Removable side covers are also provided. The wiring side is interlocked and an auxiliary link is supplied to restore power for servicing.

Specifications

Dimensions:

- Field Switching Unit
  - Case Only .... 24½" long, 8⅛" wide, 15⅛" high
  - Overall .... 26½" long, 8½" wide, 18½" high
- Field Power Supply
  - Case Only .... 24½" long, 8⅛" wide, 15⅛" high
  - Overall .... 24½" long, 8½" wide, 15⅛" high

A-c Power Input (approx.):

- Switcher and Power Unit .... 800 watts
- Switcher, Power Unit and Master Monitor .... 1150 watts

Weight:

- Field Switching Unit .... 71.5 lbs.
- Field Power Unit .... 58 lbs.

Stock Identification:

- Field Switching Unit MI-26215
- Field Power Supply MI-26095

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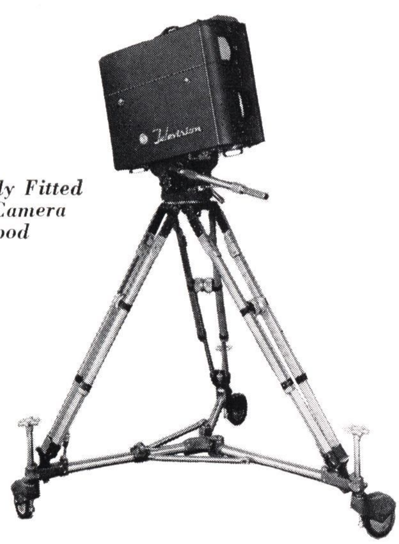
Tripod Dolly, Type TD-15A

Features

- Provides mobility for tripod camera mounting.
- Folds into compact lightweight self-locking package for carrying.
- Large diameter 5″ wheels permit easy movement.
- Wheel stops provide for locking tripod in position.
- Tripod firmly locked to dolly.
- Attractively finished in hard chrome.

Use

The Tripod Dolly is designed for use on tripods fitted with television cameras. When tripods are used indoors, which is very often the case, use of the dolly precludes any possibility of marring the floor, and provides greater mobility for the tripod. Used in the field with reasonably flat terrain, the dolly makes it convenient and easy to change the position of the tripod.



Dolly Fitted to Camera Tripod

Description

The Tripod Dolly consists of a lightweight triangular-shaped steel structure supported on three swivel wheels, five inches in diameter. The finish is hard chrome. For convenience in transporting, the dolly folds into a package 8 x 14 x 29 inches. When extended and fastened to the tripod, it occupies a circular area 57 inches in diameter. The dolly is fastened firmly to the tripod by a clamp at each leg. Spring-loaded stop feet at each wheel serve to hold the tripod in a fixed position. Also the wheels can be removed readily if such should be required.

Specifications

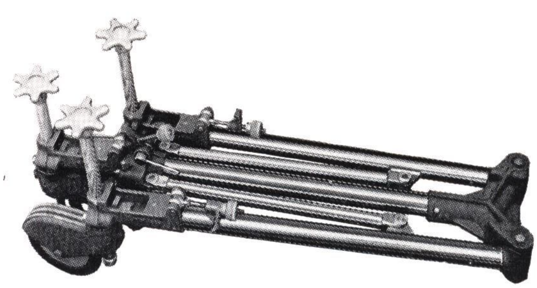
Dimensions (unfolded and extended):

Height	6 in.
Diameter	57 in.

Folded for transport:

Height	8 in.
Width	14 in.
Length	29 in.

Weight	25¼ lbs.
Stock Identification	MI-26042



Dolly Folded for Transportation

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Television Mobile Unit Type TJ-50A

Features

- Economical and convenient to maintain—standard Chevrolet school bus chassis.
- Modern styling conforms with that of RCA Television Equipment.
- Six feet of head room in interior.
- Large windows in driving compartment.
- All glass is shatterproof.
- Complete and convenient stowage facilities.
- Cables contained on six convenient reels.
- Inside ladder and hatch provides access to roof.
- Roof covered with special non-skid tread material.
- Adequate heating facilities.
- Complete control room in rear of truck.

Uses

The RCA Television Mobile Unit is a custom-built vehicle designed to carry the television equipment needed to pick up outdoor scenes and relay the pictures to a studio or transmitter room for broadcasting.

The interior arrangement provides adequate storage space for three cameras, their tripods and the relay transmitting parabola—units which must be set up outside the vehicle for telecasting. Equipment which need not be removed from the vehicle, such as the relay transmitter control unit, audio amplifier and mixer, monitors and the camera control units, are shockmounted on an attractively finished, linoleum covered operating table inside.

Use of the Mobile Unit greatly simplifies the work of transporting the television equipment required for field pickups. It also saves considerable wear and tear on the television units as well as time in setting them up for operation.

Description

The body of the vehicle, built on a standard 1½-ton Chevrolet chassis, is custom-built to provide an attractive, practical and compact unit. Finished in two-tone umber gray, it is both attractive and durable. The roof is reinforced to support the weight of the field cameras as well as the relay antenna and the operators. Access to the roof is made easy through use of an inside ladder and a 24″ x 36″ rain-tight hatch.

A short wheelbase gets the vehicle around sharp turns in narrow streets; large, full-view shatterproof windows facilitate safe driving in heavy traffic; and a 90-horsepower engine provides speed on open roads as well as pulling power on the hills.

Four cable reels mounted on swinging arms are housed in a rear compartment accessible through two doors in the back of the unit. When the rear doors are opened, the reels can be swung out into the clear to facilitate unreeling the cable. Each reel can accommodate 200 feet of cable. If additional cable is required, there is space in the compartment for the addition of two cable reels.

Inside, the vehicle has adequate heating facilities for cold weather. In warm weather, the heater fan can be used for ventilation. The linoleum covered operating table at the rear runs the full width of the Mobile Unit, and provides convenient operating space for three operators seated side by side. Swivel chairs for the operators are permanently mounted to the floor. The storage lockers for the cameras, tripods and accessories are built along the inside walls of the vehicle.

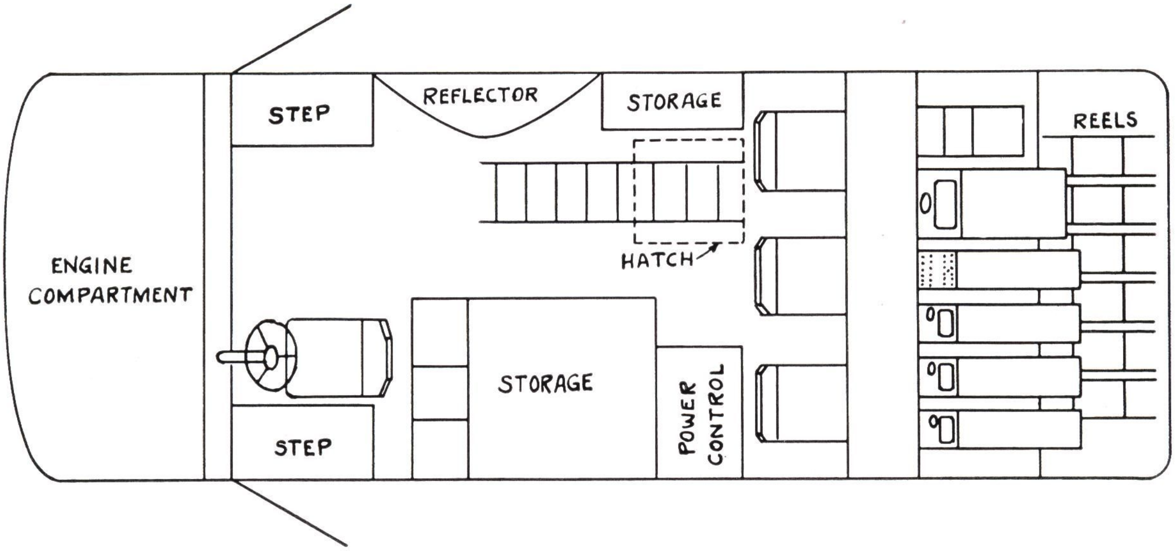
Interior view, looking aft, showing ladder to roof, and operators' positions

Specifications

Outside Dimensions (overall):
- Length (bumper to bumper) .... 269″
- Width .... 89″
- Height .... 110″

Inside Dimensions:
- Width .... 84″
- Height .... 72″
- Height (at operators' table) .... 67″

Gross Weight .... 13,500 lbs.
Tire Size .... 7.50 x 20
Chassis .... Standard 1½-ton 160″ wheelbase Chevrolet
Finish .... Two-tone umber gray (light umber gray inside)



Interior layout plan of TJ-50A

Film Projector Type TP-16B

Features

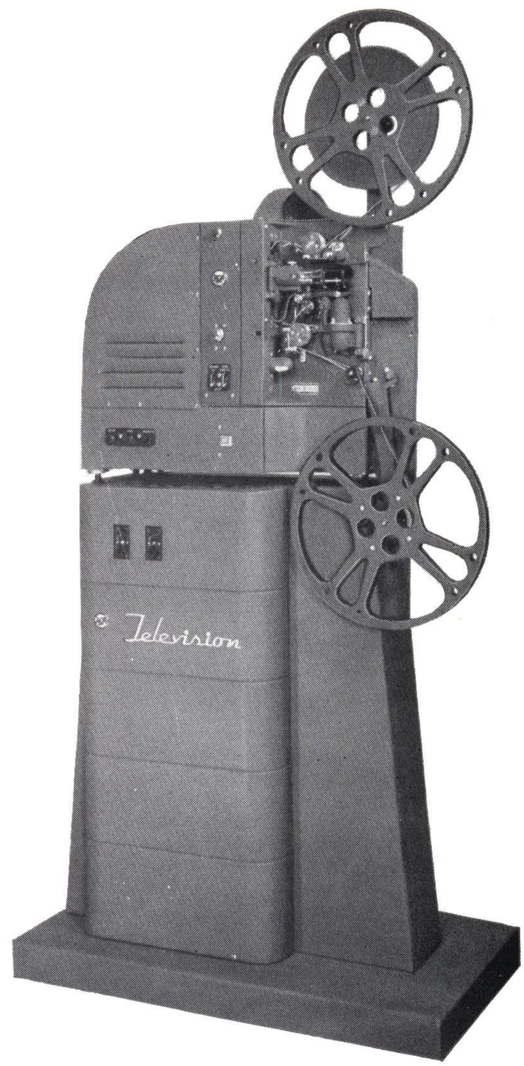
- Simple, straightforward film path provides for quick and easy threading.
- Removable film gate makes aperture cleaning easy.
- Constant light source provides utmost simplicity in design.
- Film lengths up to 2000 feet can be used without replacing reels.
- Coated lenses minimize reflections and improve contrast.
- Resolving power of lens is 60 lines per millimeter at any point in the field.
- Projector can be operated on a current supply of 50 cycles as well as 60 cycles.

Uses

The TP-16B Film Projector is used in television studios to provide regular program material using standard 16mm sound motion-picture film. To obtain the video signal, the projector is used in conjunction with the TK-20A Film Camera, and the two units are mounted in such a position that the TP-16B projects a picture directly onto the mosaic of the picture tube in the film camera.

The TK-20A Film Camera is similar to a studio camera except that it is not provided with any optical focusing system. Instead, the optical system of the projector is used to size and focus the picture which is projected on the pickup tube mosaic.

When more than one projector is used, it is not necessary to have a separate camera for each projector. If the film projectors are arranged in pairs, a mirror switching arrangement may be employed to make one camera serve both projectors, and a slide projector in addition. Since projectors are ordinarily used in pairs (for showing alternate reels) this is a very practical arrangement.



Description

The TP-16B Projector is entirely self-contained and, with the exception of the film feed arrangement, is entirely enclosed. The projector housing is provided with an attractive umber-gray crackle finish matching that of other RCA television equipment. The projector proper is mounted on a heavy cast base frame. This frame in turn is mounted by means of leveling screws on a lightweight pedestal of matching design and finish. This pedestal greatly improves the appearance and provides a convenient place for mounting the controls and field-supply for the special three-phase motor which is a feature of the TP-16B.

The mechanism of the Type TP-16B Television Projector is an adaptation of that used in RCA's outstandingly successful PG-201 Deluxe 16mm Sound Projector. The film feed arrangement, optical system, and sound pickup unit of the TP-16B are identical to those of the PG-201. The cast-aluminum frame and the front part of the projector housing are also the same. Use of these precision-made components, whose satisfactoriness is attested by thousands of PG-201's in use, not only insures trouble-free operation, but also makes it possible to provide a deluxe-type projector at a price much lower than would be entailed if these machines were special-developed and manufactured from scratch in the relatively small quantities required for television use.

The optical projection system consists of a 1000-watt air-blast-cooled incandescent lamp, a silver-coated pyrex glass reflector, a large two-element aspheric condenser lens, and a 3.5 inch, F.2 "coated" projection lens. This system provides plenty of illumination on the mosaic of the camera iconoscope and is, of course, much simpler than systems using switched or pulsed light sources.

The film feed arrangement of the TP-16B is identical to that of the standard projector with the exception that the pull-down claw works at a greater speed. Film is fed from the upper reel under a large sixteen-tooth feed sprocket and through the precision made film gate. Light, controlled by a rotating shutter, is projected through the film at this point. The film is pulled down through the gate, a single frame at a time, by the pull-down claw just below the gate.

Since television standards (and proper synchronization) require transmission of 60 fields (30 frame, interlaced) per second, and motion picture film is made for projection at 24 frames per second, some means must be provided for conversion from the one rate to the other. In the TP-16B this is done by "scanning" the first frame twice, the second frame three times, the third twice, the fourth three times, and so on. The average rate, then is 2½ scannings per frame—which, multiplied by the 24 frames per second, provides 60 scanned fields per second.

If the "pull-down" could be accomplished during the vertical blanking interval—1/750th of a second, every 1/60th of a second—no further modifications of the standard projector would be necessary. Unfortunately this is not mechanically possible. Therefore, a further stratagem is employed. This consists in the use of short light flashes so timed that the film picture is projected on the pickup tube mosaic for only 1/1200th of a second, every 1/60th of a second. These flashes occur during the vertical retrace time and are provided by a rotary shutter which consists of an 18-inch metal disc with a slot cut in its periphery. This disc is driven at a speed of exactly 3600 rpm by a special 3-phase synchronous motor. This arrangement is possible because the mosaic of the pickup tube "stores" the picture during the interval between flashes of illumination.

Synchronization of the TP-16B Projector with the television system is assured by virtue of the fact that both the television synchronizing generator (which drives the beam in the camera pickup tube) and the motor which drives the projector shutter have a common source of power. To insure that the shutter will be in step at all times a large-size motor with a separately excited d-c field is used. The d-c field, being polarized, makes the motor always "lock" in proper phase relationship with the sync generator. The power supply for the motor field is mounted in the pedestal.

Sound System

A number of unusual features are incorporated in this sound unit. One is the use of radio-frequency voltage (28 kc) on the exciter lamp filament. This prevents hum and noise from being introduced by the lamp itself. Another feature is the fact that the exciter lamp mounting and sound carriage are die-cast in one piece, thereby insuring permanent accurate alignment. Still another is the use of the famous RCA-developed rotary stabilizer on the sound drive. This maintains smoothly uniform film speed for sound take-off—a guarantee of sound reproduction at originally recorded pitch.

An audio preamplifier is built into the base of the projector. This amplifier, which is of conventional design, employs an RCA-1620 as a photo-cell amplifier, an RCA-6J7 as a voltage amplifier and RCA 6V6FT/G as an output tube. A tapped output transformer provides output impedances of 250 or 500 ohms. Output level is +4VU at 1000 cycles with less than 1% total r-m-s harmonic distortion.

The audio amplifier is assembled on a small chassis which can be easily removed from the base housing. Also mounted on this panel is the 28 kc oscillator which supplies voltage for the filament of the exciter lamp and a power supply using a 5Y3-GT/E which supplies plate voltage for the amplifier and oscillator.

A sound equalizer panel is available as an accessory for the projector sound channel and is identified as MI-26313. The unit is constructed to be mounted convenient to the audio control position so that the film sound may be easily adjusted for proper response. The compensation in frequency response is necessary because of the wide variation in recording of and printing of 16mm films. A single control is used in a tilt circuit with a straight through center position; with three high boost and three low boost positions of 2.5 db steps each.

Provision for Remote Control

Controls mounted on the projector include "Standby," "Emergency Run," "Start," "Stop" and "Remote." When the remote switch is operated, "Start" and "Stop" controls at a remote location may be used to control operation. These circuits operate through relays and a master contactor mounted on the pedestal.

Maintenance Features

Easy and quick maintenance is one of the features of the TP-16B projector. The field power supply, control circuits and all external connectors in the pedestal are easily reached by removing the pedestal side covers. The preamplifier and exciter filament supply unit are available when the cover plate, held by two thumbscrews, is removed. The projector lamp is reached through a hinged door. The film gate assembly is easily removed for cleaning. All parts of the film feed system are in the open where they may be constantly observed.

Specifications

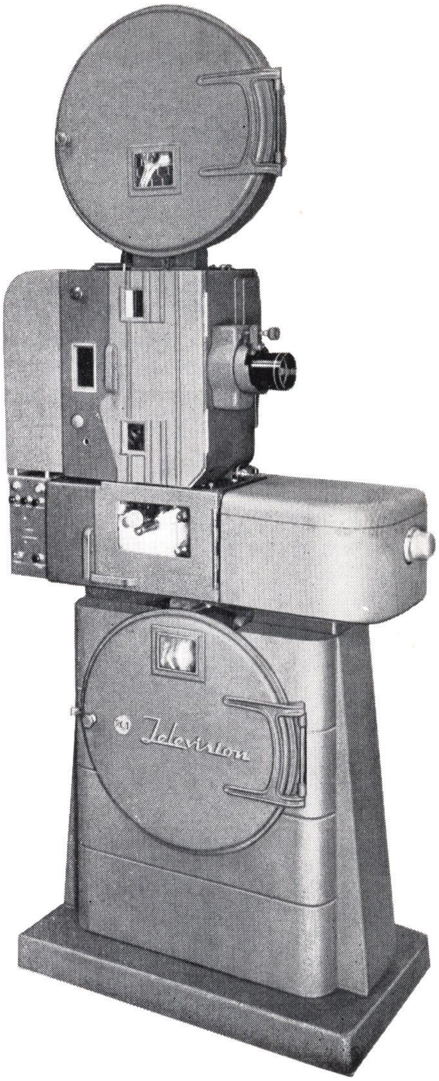
Film Type	Standard 16mm
Film Capacity	400′ to 2000′
Film Speed	24 frames per second
Shutter Speed	60 frames per second
Projector Lens Line	48″ above floor
Audio Output Power	+4 VU at 1000 cycles
Output Impedance	250/500 ohms
Frequency Response	±2 db from 80 to 3000 cycles ±3 db from 80 to 4000 cycles
Hum and Noise Level	40 db below output level
Dimensions	Height 68″; Length 32″; Width 16¾″
Weight	Projector 90 lbs.; Pedestal 135 lbs.; Total 225 lbs.
Tubes Required	1 RCA-927, 1 RCA-1620, 1 RCA-6J7, 2 RCA-6V6GT/G, 3 RCA-5U4G, 1 RCA-5Y3GT/G, Projector Lamp T-12
Power Required	
209-220 volts, three-phase	250 watts
105-125 volts, single-phase	1200 watts

PRINTED IN U.S.A.

Television Film Projector, Type TP-35B

Features

- Highly efficient pulsed light source, no shutter mechanism required.
- Quiet operation.
- Excellent picture definition.
- Completely enclosed unit—even to film magazines.
- Very little heat on film—stills of any frame of the film can be projected.
- RCA sound head used—response flat out to 6 kc.
- Light output of projector favorable for proper operation of film camera.



Use

The TP-35B 35mm Television Projector is designed for use in television stations as a means for utilizing standard 35mm sound motion picture films as program material. The TP-35B can be used as the single source of program material for the television station, or it may be alternated with "live" programs and network shows to add variety to the station's program schedule.

The TP-35B Projector is designed for use with the TK-20A Film Camera. In the simplest arrangement, the projector is mounted in such a position that it projects motion pictures directly on the pickup tube in the TK-20A Film Camera. The video signal produced by the camera is then fed to the studio control room. A single TK-20A Film Camera can serve two motion picture projectors and a slide projector by using a Multiplexer. This device employs a slide projector and two mirrors mounted at the required angle to direct the pictures from either projector onto the pickup tube of the film camera.

Description

The TP-35B Projector is entirely enclosed. The housing is finished in an attractive umber-gray crackle finish, matching that of other RCA equipment. Shatterproof glass windows permit viewing the operation of the mechanism without removing any door or cover.

Film is fed from the upper film magazine down through the film feed sprocket and through the film gate in the picture head. At this point, light produced by a pulsed-light lamp is projected through the film. The pulsed-light system eliminates the need for a shutter mechanism. It consists of an electrically operated gas-filled lamp which produces short pulses of light at the required rate of speed. The film then passes over the sound drum to the lower film magazine in the pedestal of the projector.

Also contained in the pedestal is a power supply which furnishes d-c voltage for the field of the driving motor, and a terminal board on which is mounted the relay for the pulsed-light lamp. Power for this lamp is furnished by a power supply which is mounted in the projection room control rack which contains the monitoring equipment and remote control panel. A control box on the rear of the projector contains the necessary switches for starting and stopping. For the use of two projectors, a changeover panel is provided. This panel, which is rack-mounted directly below the video monitor in the projection room, contains switches for starting and stopping either projector, and for changing over from one projector to the other. The changeover switches control relays which switch the optical systems (douse and undouse) as well as the sound circuits.

For the purpose of using standard motion picture film, which runs at an average speed of 24 frames per second, on a television system which has a basic rate of 30 frames per second, a new type intermittent has been designed. This intermittent is a 3-sided geneva movement driven at an average speed of 24 cycles per second. Pull down time is 120° (as compared to

90° on a standard theatre projector). Showing time is alternately 168° and 312° (as compared to 270° on a standard theatre projector). This arrangement permits a 5% 60-cycle light pulse to be phased so that three pulses occur during the 312° showing interval, and 2 pulses occur during the 168° showing interval. This results in 60 pictures or 30 television frames per second, while the average speed of the film remains at 24 frames per second.

The TP-35B designed for television by RCA, employs the most advanced features known to the field of film projection and its application to the production of television programs. One of the basic units of the equipment is the Brenkert BT90 Projector Head employing the special geneva movement and other features needed to meet the standards set up for the television system.

The sound head is the standard RCA high quality unit used in all Brenkert theatre projectors. For the TP-35B, it includes a special salient-pole synchronous motor. The projection lens combines the favorable features associated with high quality projection lenses, such as: flatness of field, freedom from color fringes, excellent contrast, and definition. Durable anti-reflection coatings increase light transmission and improve image contrast through elimination of internal reflections. The lens mount is hermetically sealed to prevent the entrance of dust or moisture.

Auxiliary equipment, not a part of the basic projector assembly, is normally housed in a standard cabinet rack located in the projection room. This rack-mounted equipment includes the pulsed light power supply, exciter lamp supply, remote control panels, and a 10-inch picture monitor. Controls are arranged so that either of two projectors can be started and stopped and change-over relays operated either at the projector or from the control room.

Most moving parts of the projector are automatically and continuously lubricated. A pump inside the housing delivers a continuous flow of oil from the reservoir at the base of the main frame to the rotary lubricator which throws the oil over the gears and to every bearing. An oil sight gauge provides an indication of the amount of oil in the reservoir.

Specifications

Film Type — Standard 35mm
Film Capacity — 2000′
Film Speed — 24 frames per second
Light Pulse — 5% duration—60 times per second (synchronized with flyback time of camera pickup tube)
Projector Lens Line — 48″ above floor
Projection Distance — (6½″ focal length lens)—37″
Audio Output Impedance — 500 ohms balanced
Dimensions (overall):
- Height — 6′ 3″
- Width — 16½″
- Depth — 34″

Weight — 400 lbs. (approx.)
Power Requirements (Projector):
- Projector Motor — 200 watts, 208 volts, three phase
- Projector Motor Field Supply — 100 watts, 115 volts, single phase
- Pulsed Light Supply — 450 watts, 208 volts, three phase; 200 watts, 115 volts, single phase
- Exciter Lamp Supply — 45 watts, 115 volts, single phase

Tube Complement (for Projector only):
- 3—RCA 5U4G
- 1—Exciter Lamp, 10 v., 5 a.
- 1—Type 868 Photo Cell (for Sound Head)

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Film Multiplexer Type TP-9A

Features

- Permits use of a single film camera for two film projectors.
- Employs built-in slide projector.
- Employs long life front-surface type mirrors.
- Aids program continuity.
- Introduces negligible optical distortion.
- Permits use of a stand-by film projector.
- Designed for use with 16mm and 35mm projectors.
- Employs no moving parts.

Uses

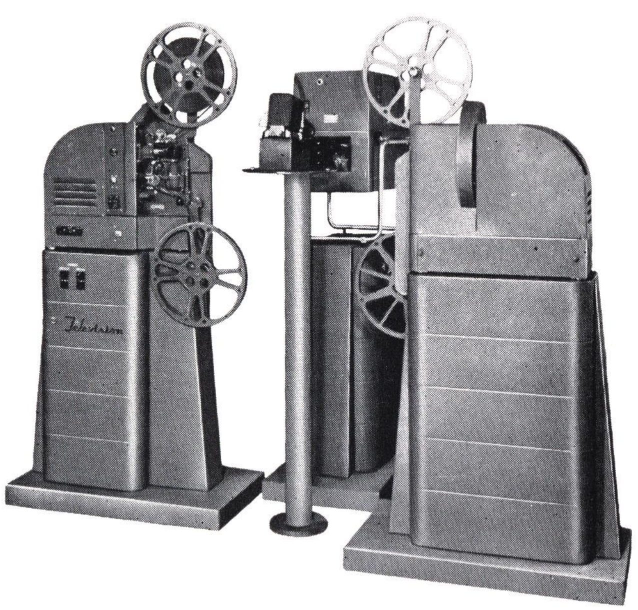
The Film Multiplexer is a device for use in the television projection room. It enables television station personnel to permanently arrange a single film camera and two film projectors so that either projector can be used with the film camera, without need for moving the units about the room.

The Multiplexer employs two mirrors mounted at the required angle to reflect the image from either projector onto the pickup tube in the film camera. In addition, a small slide projector mounted just above the two mirrors provides a means for station identification. The image from the slide projector is focused directly on the tube in the film camera.

Using the Film Multiplexer, it is also possible to have a standby film camera already set up for emergency use. The four units are then mounted opposite each other with the Multiplexer in the center. Since the mirror and slide projector assembly of the Multiplexer swivels on the pedestal mounting, the Multiplexer can be quickly swung around to serve either film camera.

Description

The Film Multiplexer consists of a cast aluminum pedestal which mounts two front-surface mirrors and a slide projector. The pedestal is fitted with a flange at the bottom for bolting to the floor. The slide projector is an Eastman Type A-2 Kodaslide Projector with a 100-watt projection lamp. The Multiplexer is finished in umber gray to match other RCA television equipment.



Typical projection installation showing Multiplexer with two TP-16A Film Projectors and TK-20A Film Camera

Specifications

Power Requirement (for projector lamp)
110 volts a-c, 50/60 cycles

Dimensions (overall):

Height	54″
Width	13″
Weight	40 lbs.
Stock Identification	MI-26318

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Film Camera Type TK-20A

Features

- Either positive or negative film can be used.
- Tubes and parts are easily accessible.
- Operation is simple—few controls are used.
- Camera can be operated 50 feet from control console.
- Oscilloscope in monitor can be used for measuring pulses.
- 10-inch aluminized tube for picture monitoring provides very bright picture.
- Clamp circuit eliminates low-frequency microphonics from video signal.

Uses

The RCA Film Camera Equipment consists of a Film Camera, a Camera Control Unit, and associated power supplies and cables. This camera chain when properly set up with a motion picture film projector or a slide projector, and supplied with synchronizing signals, will produce standard video signals which can be fed to the television transmitter. By use of an RCA Multiplexer, which is a small, compact device having two mirrors mounted at the required angle, a single film camera can be arranged to serve two film projectors and a slide projector. The TK-20A can be used with either 16MM or 35MM projectors.

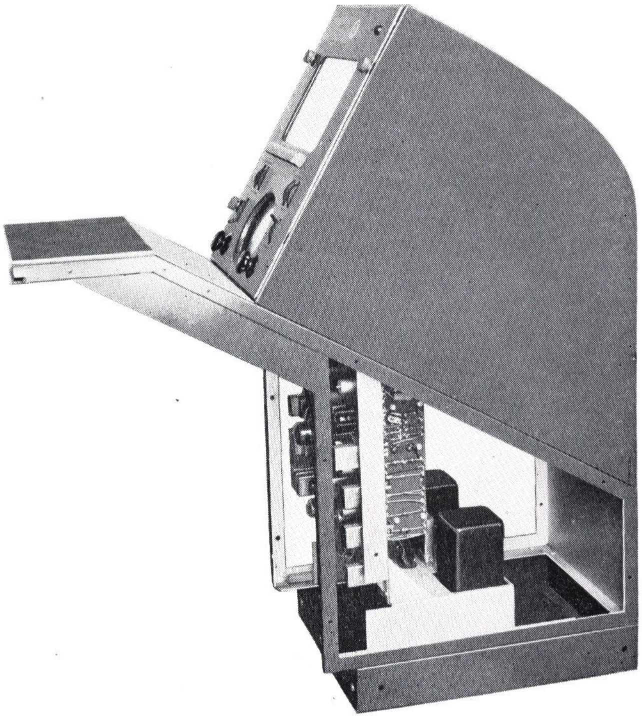
Description

The Film Camera Equipment is designed to meet the requirements of any size television station. Ordinarily, the film camera is permanently mounted to the floor in the projection room, although it also can be mounted on a wall track so that it can be moved easily to any one of several film projectors installed in the room.

The Camera Control Unit consists of a chassis type unit containing circuits for control of the signal generated in the film camera, and a Type TM-5A Camera Monitor for analysis of the video signal and observation of its picture quality. These two units are mounted in a desk-type console section which is located in the transmitter room or studio control room. This console section can be grouped with other console housings (with end sections for trim) to form a neat convenient operating desk. The monitor unit contains a 10-inch picture tube and a 5-inch oscilloscope. D-c voltages for the TK-20A camera equipment are supplied by two Type WP-33A Heavy Duty regulated power supplies. These power supplies are rack-mounted in the control room or transmitter room. The TK-20A equipment is finished in umber gray to match other RCA television equipment.

FILM CAMERA

In the illustration, the film camera is shown mounted on a pedestal, which provides for permanent mounting to the floor. If the camera is to be mounted on a wall track, the pedestal of course is not required. Contained in the film camera case



Camera Control Unit showing interior arrangement. This unit is normally housed in the master control console.

are the RCA 1850 Iconoscope pickup tube, blanking and deflection amplifiers and a 6-stage video preamplifier. Since the picture from the projector is focused directly on the mosaic of the Iconoscope, no focusing lenses are required for the film camera.

CAMERA CONTROL

The Camera Control consists of the control unit proper and the Type TM-5A Camera Monitor. The control unit contains a picture signal amplifier fed by the preamplifier in the camera, pulse line amplifiers to feed driving signals from the studio sync generator to the camera, and several controls directly associated with the operation of circuits in the camera. All components of the control unit are mounted on a chassis installed in the console desk directly below the camera monitor, the controls projecting through a sloping panel on the top of the console.

Electrically, the Camera Monitor is identical to the TM-5A Master Monitor used with the field camera equipment. It contains a 10-inch aluminum-backed Kinescope for observation of the composite video signal fed to the transmitter, and a 5-inch oscilloscope for viewing the signal waveform and for quickly and accurately measuring signal levels. A calibration circuit in the monitor permits quick reference to a fixed voltage level. Circuits in the camera monitor include separate low-capacity inputs, video amplifiers and scanning generators for both the Kinescope and oscilloscope tubes. Transformers within the TM-5A provide filament voltages for all tubes in the monitor. Plate voltages are supplied by one of the WP-33A power supplies.

POWER SUPPLIES

The Type WP-33A Heavy Duty power supplies each furnish extremely well-regulated d-c voltages at loads from 200 to 600 milliamperes. Output voltages are adjustable between 260 and 295 volts. The components are assembled on recessed type chassis for mounting in standard cabinets or open racks.

Specifications

POWER REQUIREMENTS

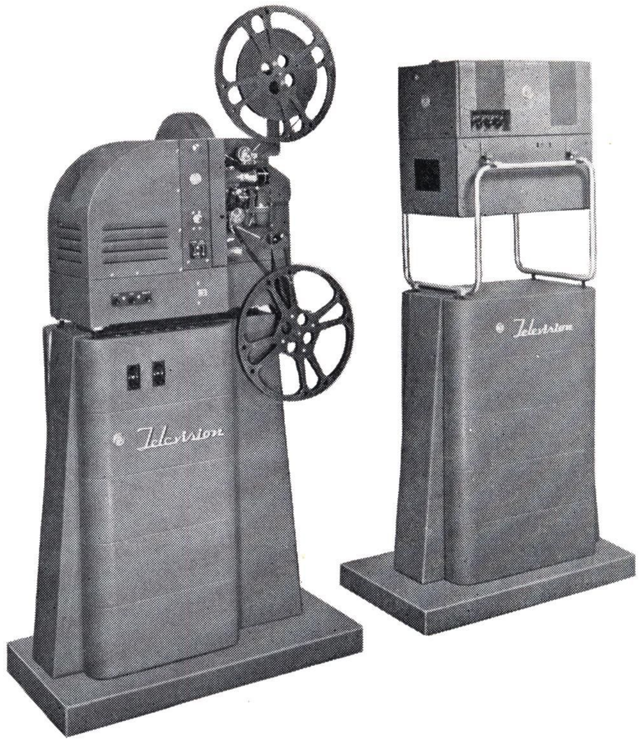
Line Rating	105-125 volts, 60 cycle, single phase
Power	1000 watts
Current	10.1 amps.
Power Factor	0.94

INPUT SIGNALS

Horiz. Drive	4 volts, 15,750 cps, 10% pulse width
Vert. Drive	4 volts, 60 cps, 4% pulse width
CRO Drive (optional)	8 volts, mixed 30 cps and 7,875 cps
Mixed Sync (optional)	4 volts, RMA signal
Mixed Blanking	4 volts, RMA signal
Communication Circuits	

OUTPUT SIGNALS

Picture Output	1.5 v. peak-to-peak (picture signal)
Remote Monitor Output	1.5 v. peak-to-peak (picture signal)
Frequency Response	Flat within 1 db to 6 megacycles
Input Impedance for Pulses	High



Typical arrangement of TK-20A Film Camera and TP-16A Film Projector

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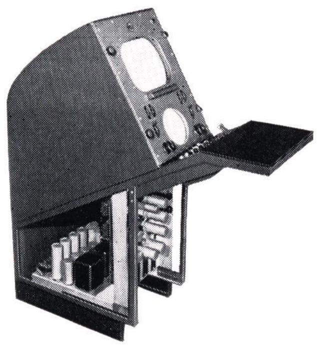
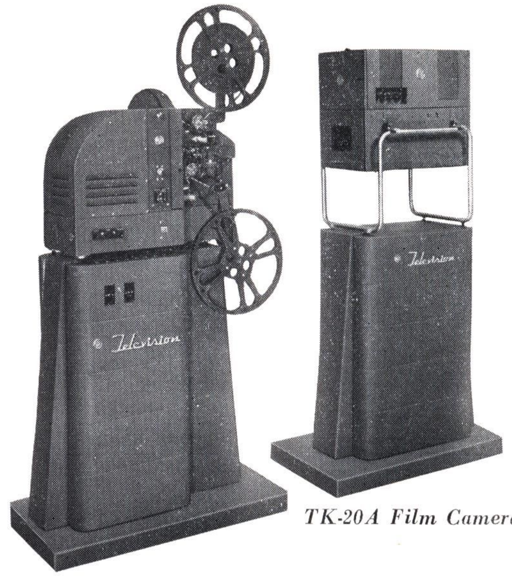
RCA Television Studio and Studio Control Room Equipment

TK-10A Studio Camera



TS-10A Switching Section



TK-20A Film Camera

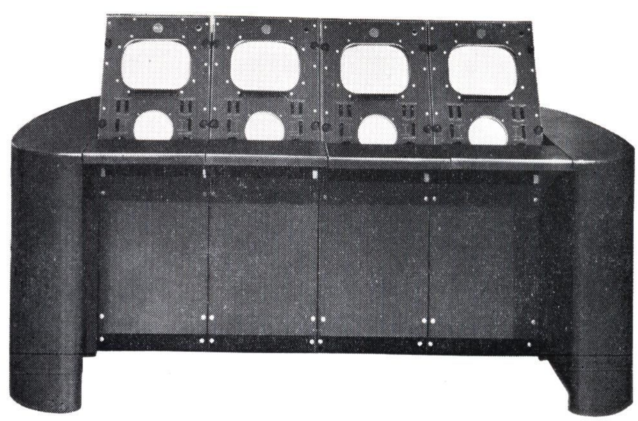
TP-16A Television Projector

RCA Television Studio Equipment is designed for all television transmitting installations, large or small. It is economical for stations starting out in a small way, because a minimum number of equipment units will handle their early requirements. As these stations grow, and new sources of program material become available, additional equipment units can be added without discarding previously installed equipment. In this way the small broadcaster can expect to have eventually a station which duplicates in appearance and facilities those stations which start on a larger scale.

RCA add-a-unit designs are also economical for larger television stations; first, because they eliminate costly duplication of apparatus, and second, because their manufacture in relatively larger quantities makes it possible to offer better quality at lower prices.

For all television broadcasters who plan to provide studio and film telecasts, there are five basic types of equipment required. These are, namely: (1) Pickup equipment, i.e., studio cameras, film and slide projectors; (2) a switching system for the cameras (or for the studios); (3) sync generating equipment; (4) program monitoring equipment; and (5) camera dollies and pedestals, line amplifiers, power supplies, etc. These items can be obtained separately, so that in each case, the broadcaster can buy to suit his particular needs. All units have matching appearance and umber-gray finish. Moreover, they are electrically and mechanically designed to operate together. Additional units can be added at any time without fear of filling studios and control rooms with a number of dissimilar components.

A typical electrical arrangement of what we consider to be the basic equipment required for even the smallest station with studio facilities is shown in the block diagram.

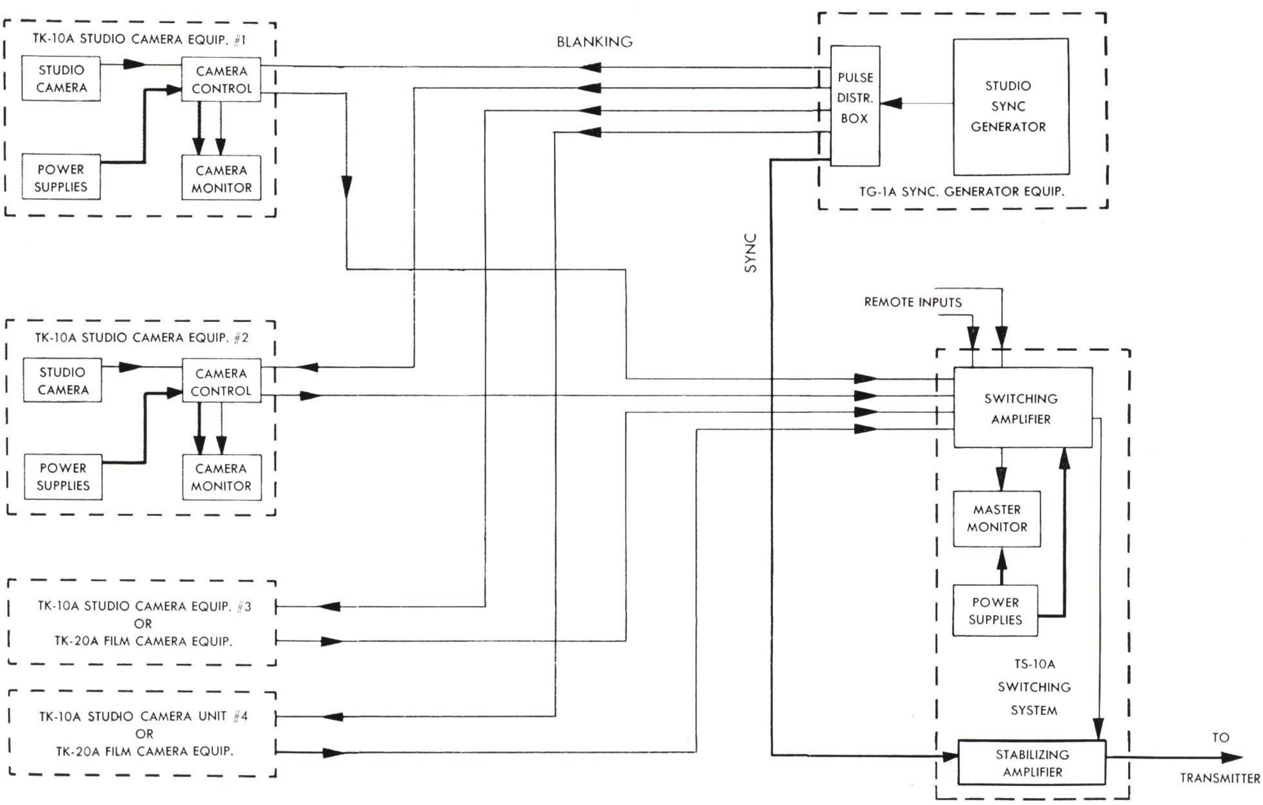


4-Section Video Console

Use is made of two Type TK-10A Studio Camera equipments, two TK-20A Film Camera equipments, a TG-1A Studio Sync Generator, and a TS-10A Switching System. The switching system can handle six input lines. As shown in the diagram, two of these six inputs are used for remote lines such as network or field pickups, and the other four are divided between two studio cameras and two film cameras. Sync is fed from the Sync Generator through a pulse distribution box to the TA-5B Stabilizing Amplifier which combines the sync with the camera video signals. Ordinarily, video signals fed to the remote inputs already contain sync which is supplied by the field equipment, or, in the case of the network input, is supplied at the station of origin. However, the Stabilizing Amplifier can also add sync automatically to remote input signals when necessary.

Program monitoring equipment required depends upon the number of studios employed by the broadcaster. For the smaller stations with perhaps one studio plus a projection room, the video console formed by the camera control units and one switching unit will in most cases be adequate for satisfactory supervision and direction of programming. This video console is made up by bolting side by side one camera control section from each camera equipment plus a switching section. The addition of trim end-sections then forms an attractive desk-type console. Any number of these units can be fastened together.

Stations employing several studios and facilities for network programs will require a program director's console. This console is styled similarly to the video console, but the viewing monitors are built inside the housing and viewed through an opening in the top of the console. Thus, light cannot strike the screens. The director's console is provided with three monitors, two for preview and one for the program line. A switching panel allows the director to fade, lap-dissolve and switch the video signals.



Block Diagram showing Schematic Arrangement of Studio Pickup and Control Room Equipment

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Studio Camera Type TK-10A

Features

- Camera does not require costly, uncomfortably-hot lights.
- Camera mounting designed for a standard tripod, a crane type dolly or studio pedestal.
- Four lens positions provided on a rotatable turret.
- Optical focusing easily accomplished by a knob on the side of the camera.
- Hinged doors and covers permit easy access to camera circuits and controls.
- Four tally lights, two on the front of the camera, one on rear of camera and one beside the viewfinder kinescope, indicate to the cameraman and performers when the camera is on-the-air.
- A combination microphone and headset for each operator produces program sound in one earphone and order wire conversation in the microphone and other earphone.
- Two phone jacks on camera—one for cameraman, one for production man.

Uses

The TK-10A Studio Camera Equipment is designed to pick up scenes produced in television studios, and provide composite video signals that can be fed to a television transmitter.

The camera uses a studio-type Image Orthicon pickup tube (RCA type 5655) which requires much less light than former studio cameras employing the Iconoscope pickup tube. Under normal lighting conditions (100 to 200 foot-candles) an excellent picture is obtained. In fact, the quality of the picture compares favorably with that produced by the Iconoscope operating with light values of 1000 foot-candles.

Description

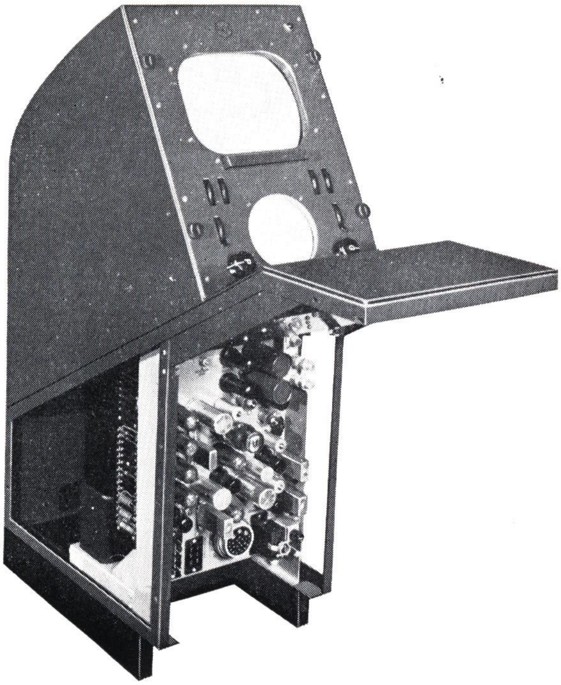
The TK-10A Studio Camera Equipment consists of the Camera itself, which can be mounted on a crane type dolly or studio pedestal, a Camera Control mounted in a desk-type console section, and power supplies designed for rack mounting. The size and general appearance of the console section is identical to that of the Film Camera Equipment and the Studio Switching System. Therefore, the studio camera control unit can be used in conjunction with other studio and film units. Any number of these console sections (one for each camera) can be bolted together to form a convenient desk-type console.

STUDIO CAMERA

The general arrangement of the controls and components of the Studio Camera resembles that of the RCA Field Camera. Like the field camera, the studio camera employs image orthicon deflection circuits, a picture preamplifier, and an electronic viewfinder which is mounted directly on the camera. The viewfinder, which enables the camera man to view the scene he is picking up, uses a 5 inch picture tube (RCA-5FP4A) which operates with an image brightness satisfactory for viewing scenes even in brightly lighted studios. Camera circuits are arranged on either side of the tube and coil assembly. On one side, the video preamplifier tubes are mounted on a shelf with the circuit components easily accessible on a terminal board below the shelf. The deflection and high voltage pulse supply circuits are mounted in a similar manner on the other side of the camera. Hinged doors on either side of the camera swing down to provide easy access to the camera circuits.

Four EKTAR type lenses are mounted on a lens turret which can be rotated by a handle at the rear of the camera. These lenses are relatively small due to the small size of the photocathode in the pickup tube. They are available in sizes from 35 mm f2.8 to 13 inch, f3.5 Optical focusing is accomplished by adjustment of a knob on the side of the camera. This knob moves the pickup tube and its focus and deflection coil assembly with respect to the lens.

Controls for the studio camera circuits are located on the rear of the camera in two rows behind hinged covers. All these controls are normally preset and do not require adjustment during a program. Communication and tally light circuits are provided in the camera cable.



Studio Camera Control Unit

STUDIO CAMERA CONTROL

The Studio Camera Control enables the video operator to monitor and control the quality of the picture signal produced by the studio camera. It is a desk-type console section with a TM-5A camera monitor mounted in the upper part, and the control chassis mounted in the compartment below. The camera monitor has a 10-inch picture tube for displaying the picture, and a 5-inch oscillograph tube which reproduces the picture signal waveform. Controls for gain and black level setting are brought out on the monitor front panel.

The control chassis contains the necessary circuits for amplifying the video signal, establishing black level, mixing in a sawtooth correcting signal, adding picture blanking to the picture signal, adding the synchronizing signal, and providing 3 separate outputs. It is a vertically mounted chassis with a bracket projecting from the top part of the chassis supporting the operating controls. Four commonly used controls project through the desk top surface. These are:

1. Orthicon Focus
2. Beam Current
3. Target
4. Image Focus

Three less frequently used controls are recessed under a small panel in the top surface.

The control unit complete with its controls can be removed easily from the console by removing the lower front panel and sliding the unit out. All electrical connections are made with plug-in connectors.

POWER SUPPLIES

Four power supplies are required for each camera chain. These are as follows:

1. Type WP-33A to supply B+ to master monitor.
2. Type WP-33A to supply B+ to camera and viewfinder.
3. Type 580-C to supply B+ to camera control and to current regulator.
4. Current regulator to supply constant current to camera focus coil.

These four power supplies are designed for mounting in a standard rack in the studio control room.

Specifications

Number of Lines	525
Odd Line Interlacing	2 to 1
Frame Rate	30 per sec.
Field Rate	60 per sec.
Picture Signal Level	1.5 volts, peak-to-peak max. (conforms to RMA standards)
Picture Polarity at Output	Black negative
Impedance of Coaxial Transmission Line	75 ohms
Maximum Length Camera Cable	1000 ft.
Total Included Angle of Lenses:	
(a) 35 mm f2.8 Ektar	50°
(b) 50 mm f1.9 Ektar (3 lenses furnished)	34°
(c) 90 mm f2.8 Ektar (3 lenses furnished)	20°
(d) 135 mm f4.5 (3 lenses furnished)	13°
(e) 8.5 in., f3.9 Ilex	8°
(f) 13 in., f3.5 Ilex	5°
Incident Illumination (min.)	25 foot-candles
Incident Illumination for Best Results	100 to 200 foot-candles
Power Source	117 volts, 60 cycles
Power Consumption:	
(a) Heater Supply Camera Control	375 watts
(b) Two WP-33A Power Supplies	800 watts
(c) One 580-C Power Supply	370 watts
(d) Current Regulator	15 watts
Total for One Camera Chain	1560 watts

MECHANICAL SPECIFICATIONS

Camera (including Viewfinder)	
Length	35″
Width	13″
Height	20″
Camera Control Console:	
Depth	36″
Width	13¼″
Height (overall)	41″
Weights:	
Camera (including Viewfinder without lenses)	105 lbs.
Camera Control Console Assembly (including Master Monitor)	140 lbs.
Camera Cable	0.4 lbs. per foot

Close-up of Camera Control Unit controls (on sloping panel to right of TM-5A Monitor)

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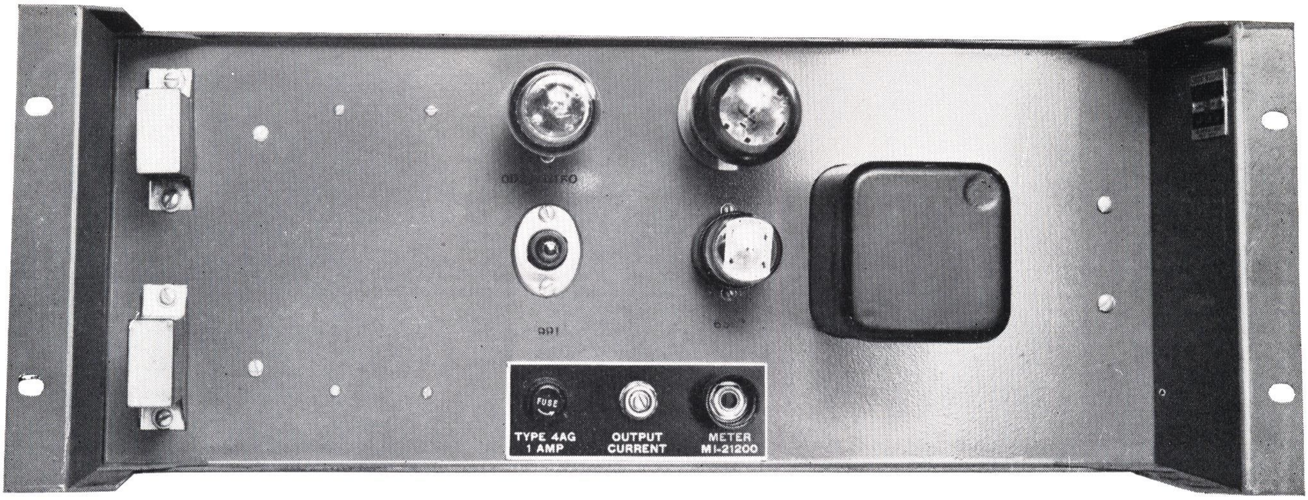
Current Regulator MI-26090



Features

- Counteracts current variations in camera focus coil circuit.
- Current can be manually adjusted over a range from 65 to 85 milliamperes.
- Common tube types are employed.
- All tubes easily replaced from front of unit.
- Designed for standard racks and cabinets.

Use

The Current Regulator is an electronic device which maintains constant current in the focus coil of the TK-10A Studio Camera. Variations in the magnitude of current flowing through the coil are brought about by temperature changes, which would ordinarily impair the focus of the camera. The Current Regulator counteracts these variations and also provides a means for adjusting the focus coil current to the proper value.

Description

All components of the Current Regulator are mounted on a recessed chassis designed for rack mounting. The unit employs an RCA 6SL7-GT twin triode as a d-c amplifier, and an RCA 6Y6-G current regulator tube. The cathodes of the d-c amplifier are kept at fixed levels by voltage regulator tubes.

The 6Y6-G current regulator tube is effectively in series with the camera focus coil and its 400-volt source of d-c so that the internal resistance of the 6Y6-G, which is controlled by the d-c amplifier, determines the magnitude of current flowing in the coil circuit. The input of the d-c amplifier is connected across a small resistor also connected in series with the focus coil. Thus variations in the voltage developed across the small resistor (as a result of current changes in the focus coil circuit) are fed to the d-c amplifier which in turn raises or lowers the conductance of the 6Y6-G to counteract the current change taking place. Regulation is, of course, instantaneous and the result is a constant flow of current through the focus coil of the camera. The Current Regulator will maintain constant current at a preset value over wide ranges of resistance change in the load and over wide ranges of input voltage.

Specifications

Power Requirements:
A-c ______ Single phase 117 volts, 60 cycles, 15 watts (for fil. transformer)
D-c ______ 400 volts from Type 580-C Power Supply

Chassis Dimensions:
Depth ______ 5½″
Width ______ 19″
Height ______ 8″
Weight ______ 9 lbs.

Tube Complement:
1—RCA 0D3/VR150 Voltage Regulator
1—RCA 991 Voltage Regulator
1—RCA 6SL7-GT D-C Amplifier
1—RCA 6Y6-G Current Regulator

2J4905-M

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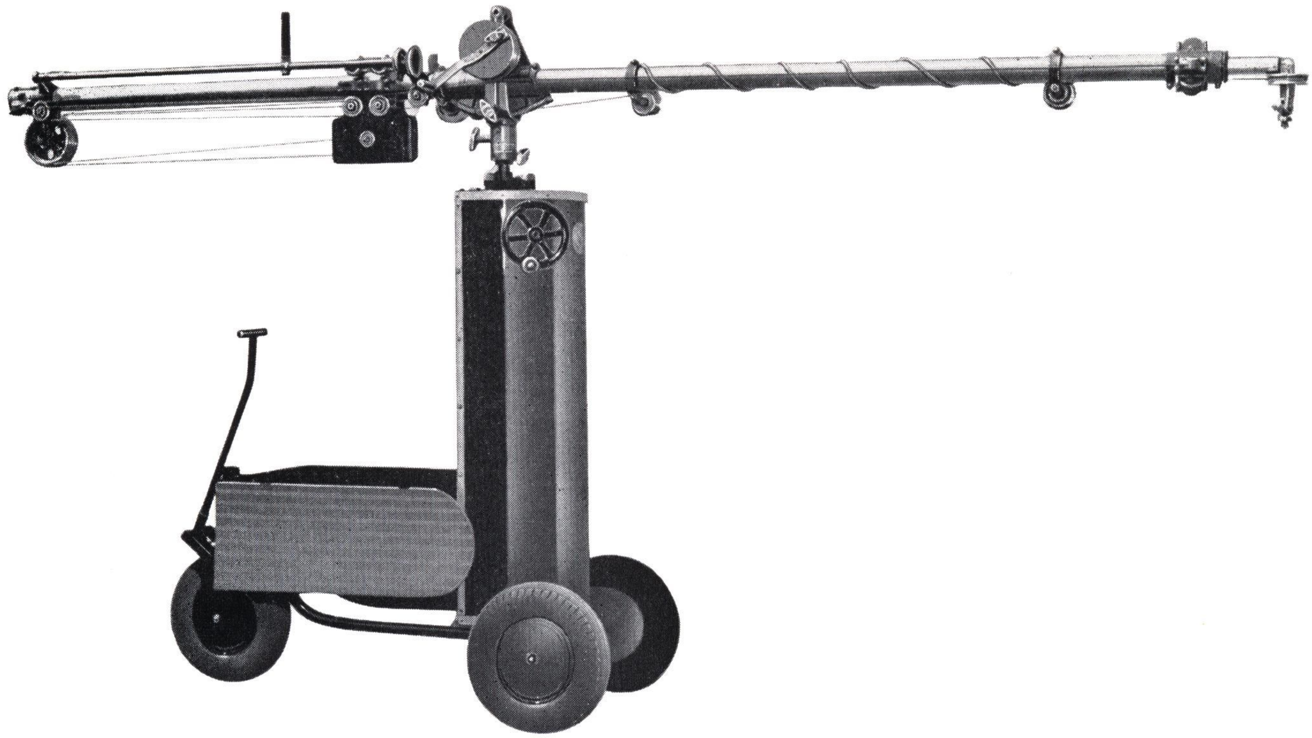
Microphone Boom & Perambulator MI-26574



Features

- Boom and perambulator can be passed through narrow doorways.
- Duraluminum tubing for boom assures rigidity and light weight.
- "Gunning" device revolves directional microphones through 280°.
- Radius of boom can be extended to 17 feet—retracted to 7 feet, 4 inches.
- Boom fitted with adjustable counterbalance for different microphones.
- Quiet in operation.

Use

The MI-26574 Microphone Boom and Perambulator is designed for use in broadcast or television studios. It enables the operator to quickly place the microphone with respect to the sound source. He can closely follow the sound, or move from one source of sound to another easily and quietly.

Description

The perambulator is constructed of steel tubing with drop-rim type wheels and pneumatic tires. The steering wheel swivels 180° and can be clamped to hold a given radius. The tiller when pushed back operates a toggle brake on the steering wheel. It is also provided with steps which aid the operator in mounting the platform when it is elevated. Operated by a hand wheel, the elevating column raises the boom from a height of 6 feet, 5 inches to 9 feet, 5 inches. The operating platform raises with the boom. The wheel tread of the perambulator can be narrowed to 27 inches and the leaf portions of the table can be lowered to permit passing the perambulator through a 30-inch door.

A hand crank governs extension and retraction of the boom, and a hand rail controls elevation and horizontal traversal. As the boom is retracted, the microphone cable is received on take-up sheaves. The movement of the telescoping member is counterbalanced by weights which can be adjusted to properly balance different microphones. Since many microphones are directional, the boom is fitted with a "microphone gunning" device which revolves the microphone through 280°.

Specifications

Dimensions:

Maximum Height (with boom pedestal elevated)	9′ 5″
Maximum Height (with pedestal lowered)	6′ 5″
Length of Boom:	
Extended	17′
Retracted	7′ 4½″

Weight:

Boom (with gunning device)	66¾ lbs.
Counterweights for Boom	35¼ lbs.
Perambulator	421 lbs.

2J4905-N

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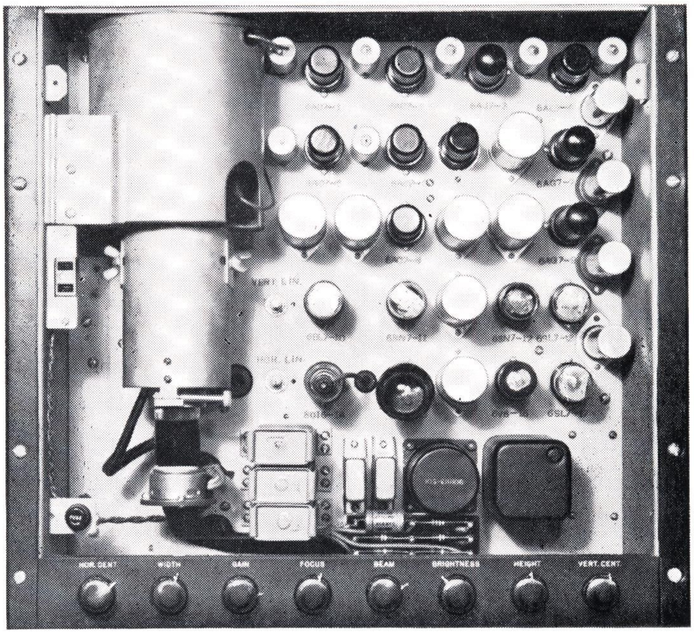
Monoscope Camera Type TK-1A



Features

- Useful to television transmitting station, laboratory, factory, or service bench.
- Compact construction; bathtub chassis.
- Built-in high voltage power supply.
- Pattern shows scanning symmetry, vertical and horizontal resolution, shading, reproduction of isolated details, contrast and brightness.
- Accessible arrangement.

Uses

The Type TK-1A Monoscope Camera may be used as a convenient means of obtaining an image for video testing of television transmitting equipment, or a "test pattern" to be transmitted during warm-up and stand-by periods. In the latter case, the station call letters may be made a part of the pattern, thereby providing station identification. It may, likewise, be used in the television transmitting station as a readily available source of video signal, of known quality, to be used in place of the studio camera when making tests or adjustments on other units of the system. In the laboratory, factory, or service bench, the equipment may be used as a source of video signal to test or adjust television receivers, video amplifiers, and picture tubes. With the addition of a source of blanking and driving signals, an IF sweep generator and an RF signal generator, it produces a complete television picture signal simulating that received off the air, and thus provides a means of testing receivers under conditions equivalent to actual use.

Description

The TK-1A Monoscope Camera comprises the monoscope tube, the scanning generators, the video output amplifiers, and the high voltage power supply for the monoscope tube. This equipment is built on the familiar recessed bathtub type of chassis which fits into a standard nineteen-inch rack. All tubes and large components are located on the front of the chassis, while the wiring and smaller components are on the rear. The controls are grouped on a narrow control panel along the bottom of the chassis. When installed and in operation, the front is covered by a large cover plate which conceals everything but the control panel. This cover plate is interlocked to protect operating personnel from the high voltages present in the equipment.

The monoscope tube in the TK-1A is mounted in a vertical position at the left of the chassis. The upper part of the tube is enclosed in a mu-metal shield. The magnetic deflecting coils are mounted within the shield, and are attached to it. By disconnecting the tube socket, anode, and signal leads, the whole assembly—tube, coils, and shield—may be swung outward. This arrangement allows the tube to be changed very easily, and, at the same time, is very economical of rack space.

The monoscope tube ordinarily used in the TK-1A is an RCA-2F21. This tube provides a pattern which combines the features of several previously used tubes. It shows the following details of the quality of reproduction in a given television system: scanning symmetry, resolution in both vertical and horizontal directions, shading and reproduction of isloated details. In addition it provides a pattern to facilitate proper adjustment of contrast and brightness.

The Vertical Deflection Generator consists of four tubes and associated circuits. The first of these tubes amplifies the driving signal received from the synchronizing generator and generates a sawtooth voltage wave which is amplified in the second, third, and fourth tubes. The output is applied to the magnetic deflecting coils of the monoscope tube. Negative feedback is employed to improve scanning linearity.

The Horizontal Deflection Generator includes three tubes and associated circuits. The first tube is the driving signal input amplifier and sawtooth voltage generator; the second and third tubes amplify the output wave and feed it to the horizontal deflecting coils of the monoscope tube.

The Blanking Amplifier is used to provide the proper level and polarity of the blanking pulses received from the synchronizing generator before these pulses are fed into the Video Amplifier for mixing with the video signal.

The Video Amplifier includes six stages of video amplification—together with a clipper stage which is inserted between the fifth and sixth stages. The monoscope output signal is fed directly into the first stage of this amplifier, and the blanking signal is introduced in the output of the fourth stage. The output of the fifth stage (which contains both video and blanking signals) is fed to a clipper stage which adjusts the height of the blanking "pedestals". The clipper feeds an output stage which consists of two tubes having their grids tied in parallel, but with the plate circuits separate. This provides two separate outputs—one of which may be used to feed a monitor, while the other is usually connected to a distribution amplifier.

Specifications

Output Voltage—1.5 volts peak to peak

Power Supply Required:
- Blanking, Horizontal Drive and Vertical Drive Pulse Inputs (neg. polarity)—3.5 to 5 volts
- Resolution Capability—At least 450 lines

Power Consumption:
- 110-120 volts a-c 60 cycles—100 watts
- 280 volts d-c (from Type 580-C Power Supply)—200 ma.

Dimensions—17½″ high, 19″ wide, 11″ deep

Weight—55 lbs.

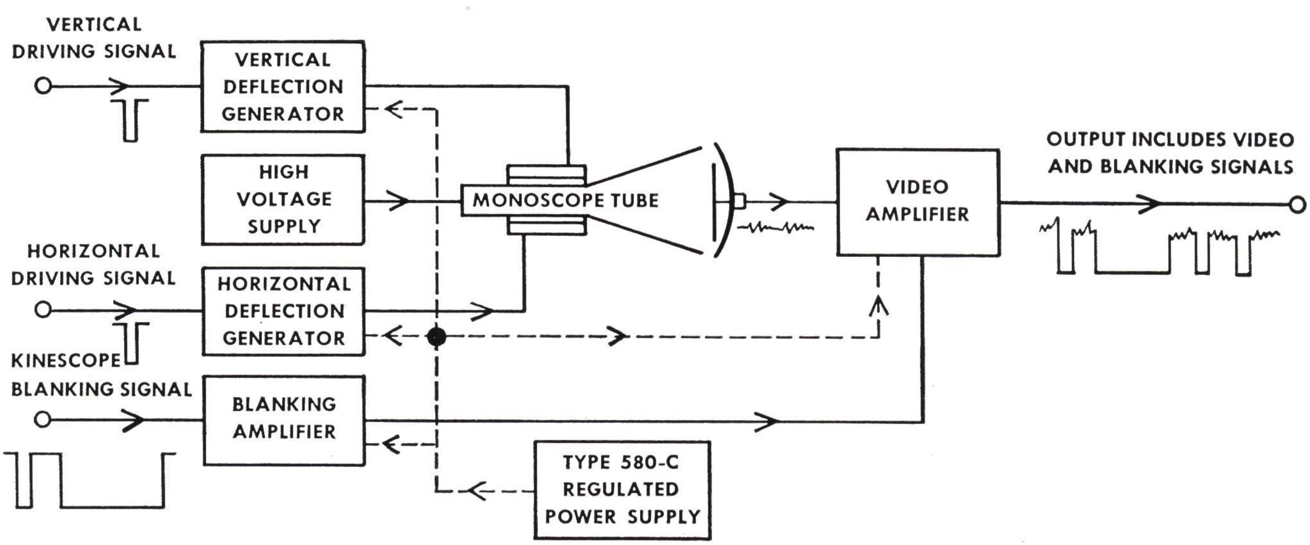
Tube Complement:

6 RCA 6AC7	1 RCA 8016
1 RCA 6H6	1 RCA 6Y6
3 RCA 6AG7	1 RCA 6V6-GT
3 RCA 6SL7-GT	1 RCA 2F21

Stock Identification—MI-26960

Accessories

Tube Kit (complete tube complement)—MI-26679

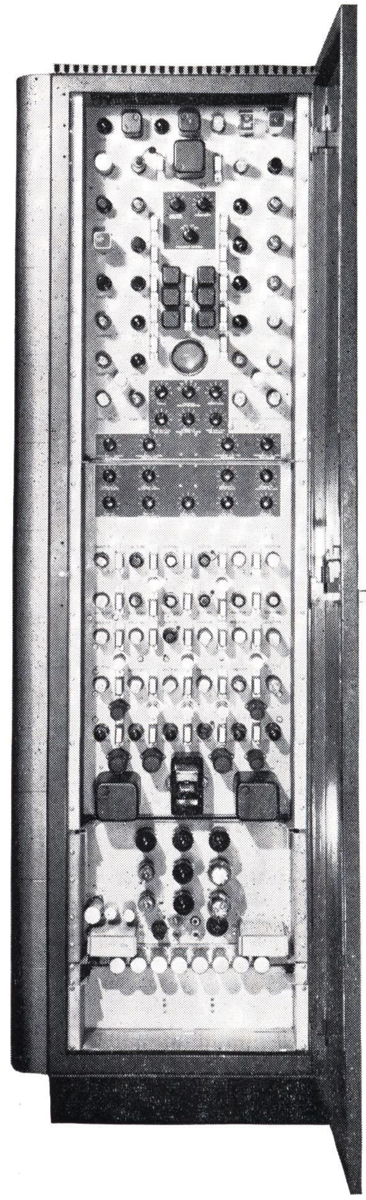


BLOCK DIAGRAM OF THE TYPE TK-1A MONOSCOPE CAMERA

Synchronizing Generator Type TG-1A

Features

- Special circuits which maintain the timing of the leading edges of the equalizing pulses, the horizontal synchronizing pulses and the vertical synchronizing pulses, with extreme accuracy.
- An improved locking circuit for synchronizing the generator with the 60-cycle power supply—or with a remotely generated synchronizing wave form.
- Use of circuits which are relatively insensitive to large changes in tube characteristics, so that ageing of tubes will not affect operation of the equipment.
- Operation of all tubes in extremely conservative manner, so that a very long, useful life may be expected.
- Wiring which has been greatly simplified by carefully grouping components so that all leads are very short.
- A built-in oscilloscope which, by means of a selector switch, can be used to check the step-down ratio of any of the frequency-dividing counter circuits.
- A regulated plate voltage power supply unit which, with the other panels, is mounted in place and wired at the factory. The unit is ready for operation immediately on installation.



Uses

The TG-1A Synchronizing Generator is designed for use in television transmitting stations as a source of synchronizing pulses for the studio and film cameras, the monoscope camera, the monitoring oscilloscopes, and the mixing amplifier (which adds the synchronizing pulses to the transmitted video signal). In laboratories and factories it is used in conjunction with a monoscope camera to furnish a complete RMA standard video signal voltage which can be used in the development and production testing of television receivers.

Description

The Type TG-1A Synchronizing Generator is an integral unit complete with power supply. It is assembled in a standard cabinet-type rack which is 84 inches high, 22 inches wide and 18 inches deep. The rack has front and rear doors which open the full length and width of the unit. This type of rack has been standardized for all RCA television, broadcast, and communications terminal equipment. Moreover, all RCA Television and FM transmitters are made up of racks which are similar in appearance, construction and height (although of greater width). Therefore, the TG-1A Generator, and other units mounted in similar racks, may be installed as needed, with assurance that they will match in appearance, other terminal and transmitting units which may be added later.

The 60 tubes and other components which make up the circuits of the TG-1A Generator are mounted on bath-tub type chassis which are placed in the cabinet vertically, as shown in the illustration. A 29¾ inch chassis at the top of the cabinet contains the "pulse forming" circuits. Immediately below is a similar chassis containing the "pulse shaping" circuits. The 10½ inch chassis near the bottom is a standard Type 580-C Power Supply Unit, and just below is a 1¾ inch chassis containing electrolytic filter capacitors.

All of the controls, tubes and major components are mounted on the front of the vertical chassis. Thus, all ordinary adjustments, as well as routine checks, can be made by opening the front door. Since no high voltages are exposed on the front of the chassis, this door is not interlocked. Wiring and minor components, such as small capacitors and resistors, are on the back of the panels, and are accessible through the rear door. All terminals are in the clear, and components are identified so that circuit testing, when required, is relatively easy.

Electrically, as well as mechanically, the TG-1A Generator is divided into two main sections. The first section comprises the "pulse-forming" circuits while the second section comprises the "pulse-shaping" circuits. The "pulse-forming" unit generates all of the different timing frequencies which are required by the system. It also provides a means whereby these frequencies (which are all derived from a single master oscillator) may be "locked in", either with the local 60-cycle power line frequency, with a crystal oscillator, or with some other external source, such as a remotely generated synchronizing wave form. The "pulse-shaping" unit forms the pulses into the proper wave shapes and combines them as required to provide the five different signals listed below. These signals are fed to ten output connectors located on a subpanel at the base of the "pulse-shaping" unit.

It is intended that RG11/U or RG59/U concentric lines be used between these points and the studio cameras, mixing amplifiers, etc. Two coaxial output connections are provided for each signal so that output of either negative or positive polarity is available. When more than one equipment is fed from a single output, a distribution amplifier, such as the Type TA-1A, should be employed in order to isolate the circuits.

Regulated plate voltages for the "pulse-forming" and "pulse-shaping" units are furnished by the Type 580-C Power Supply. Filament voltages are provided by transformers mounted on the units themselves. All a-c power input to the cabinet is controlled by the circuit-breaker switch at the bottom of the "pulse-shaping" unit.

The Type TG-1A Synchronizing Generator furnishes all of the timing pulses required in a complete television system. These pulses are accurately timed with relation to each other, and are carefully controlled as to wave form in accordance with the standards adopted by the RMA. The five different output signals which are generated will provide all of the timing and synchronizing requirements of a standard 525-line, 30-frame, interlaced television system. These five output signals are:

(1) HORIZONTAL DRIVING SIGNAL

This consists of short-duration, square-wave pulses at horizontal scanning frequency (15,750 cycles). These pulses are used to "trigger" the saw-tooth wave generator (in the camera) which supplies the horizontal scanning voltage for the pickup tube.

(2) VERTICAL DRIVING SIGNAL

This consists of square-wave pulses of somewhat longer duration which occur at vertical scanning frequency (60 cycles). These pulses are used to "trigger" the saw-tooth wave generator (in the camera) which supplies the vertical scanning voltage for the pickup tube. The width of these pulses is sufficient to blank out the vertical return trace of the camera tube.

(3) SYNCHRONIZING SIGNAL

This is the signal which must be added to the camera picture signal before it is transmitted in order to synchronize the scanning action in the receiver. It is a composite signal consisting of (a) short-duration, horizontal synchronizing pulses at 15,750 cycles, (b) longer duration, vertical synchronizing pulses of the "serrated" type at 60 cycles, and (c) a series of six short-duration, equalizing pulses just preceding each vertical pulse interval and six more following it. All of these have the timing and wave shape prescribed by the RMA Standards.

(4) KINESCOPE BLANKING SIGNAL

This signal is added to the transmitted video signal in order to blank out the return trace in the receiver picture tube (kinescope). It consists of square-wave pulses at horizontal scanning frequency (15,750 cycles) and vertical scanning frequency (60 cycles). These pulses are of longer duration than the synchronizing pulses and are transmitted at approximately "black" level. They form the "pedestals" on which the synchronizing signals are placed.

(5) OSCILLOSCOPE DRIVING SIGNAL

This signal consists of pulses at half horizontal (7,875 cycles) and half vertical (30 cycles) frequencies. They are used to trigger the saw-tooth generator in the monitoring oscilloscope, thus providing (for "wave form" monitoring) oscilloscope patterns which are two lines or two fields in length.

Specifications

Output Voltages

Synchronizing Signals (pulses as shown above black level in the FCC drawing below) — 4 volts, peak-to-peak across 75 ohms
Kinescope Blanking Signal (pulses as shown below black level on FCC drawing below) — 4 volts, peak-to-peak across 75 ohms
Horizontal Driving Signal (for actuating camera horizontal scanning circuits) — 4 volts, peak-to-peak across 75 ohms
Vertical Driving Signal (for actuating camera vertical scanning circuits) — 4 volts, peak-to-peak across 75 ohms
Oscilloscope Driving Signal (for actuating oscilloscope for wave form monitoring) — 8 volts, peak-to-peak across 75 ohms

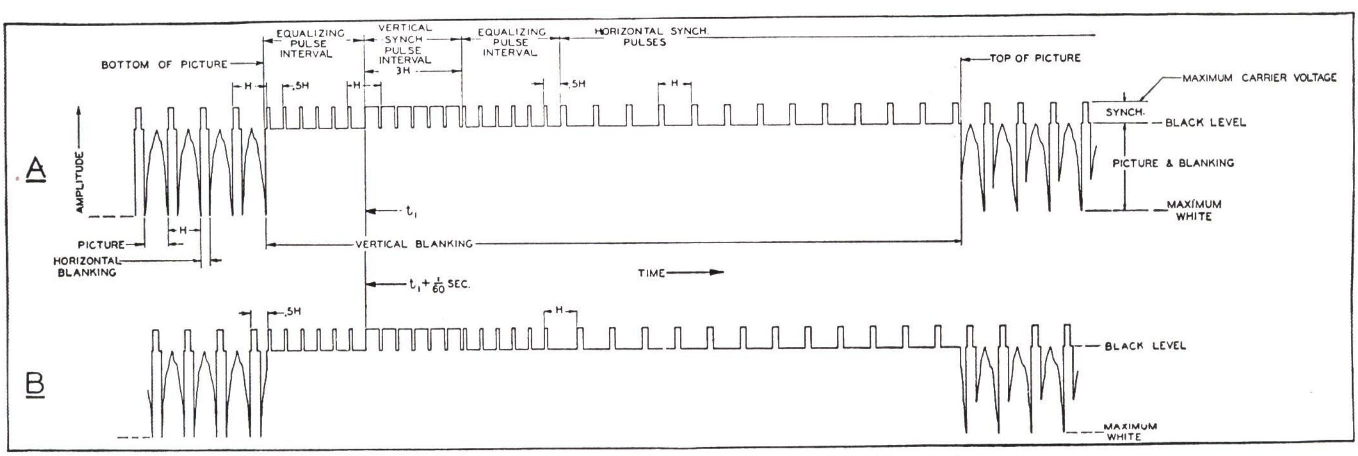
Power Supply Required
From 120 volt, 60 cycle, single phase line — 450 watts

Dimensions
Mounted in Cabinet — 84″ High, 22″ Wide, 18″ Deep
Unmounted Rack Units — 77″ High, 19″ Wide, 12½″ Deep
Weight (in cabinet) — 375 lbs.
(unmounted) — 160 lbs.

Stock Identification — MI-26915

Accessories

Front Door — MI-30536-G84
Side Panel (single) — MI-30541-G84
Monogram — MI-30596



Comparison of odd-line and even-line synchronizing pulses

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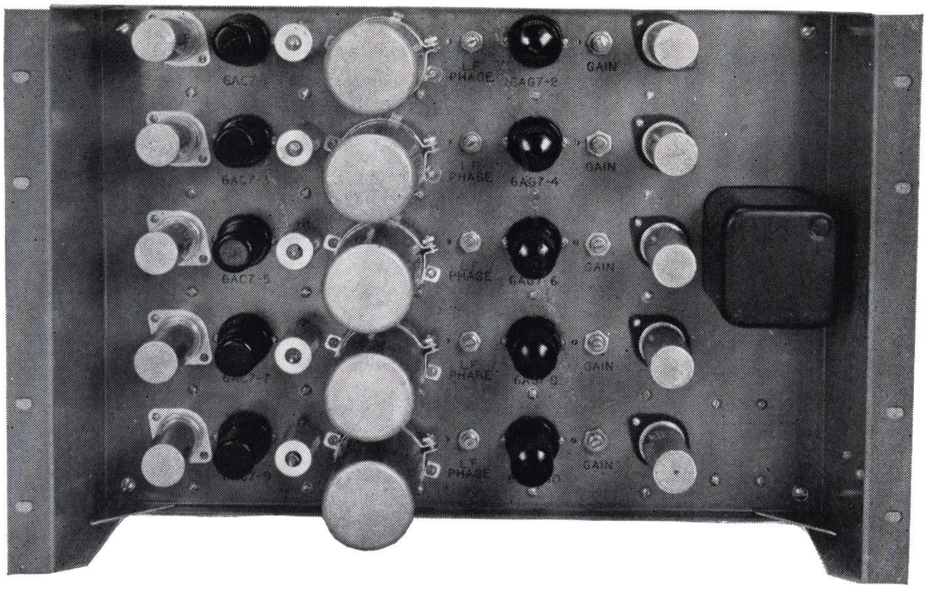
Distribution Amplifier Type TA-1A



Features

- Equally useful as distribution, mixing or isolation amplifier.
- Five amplifiers on one chassis.
- Bridging inputs.
- Excellent isolation between units.
- Positive or negative polarity.
- Standard "bath tub" type chassis.
- Accessible mounting arrangement.

Uses

The Type TA-1A Distribution Amplifier may be used in any one of the three following applications: (a) to feed video or synchronizing signals from a single source to several separate outlets; (b) to mix video signals from several sources in order that they may be fed to a single output line; (c) as a straightforward isolation amplifier requiring voltage gain of not over 15 db, by paralleling all five channels. The wide variety of possible uses of this equipment makes it equally adaptable to test bench, laboratory, or television transmitting installations.

Description

The equipment consists of five separate video isolation amplifiers mounted on a single chassis. These amplifiers are of the bridging type, and have relatively high input impedance, permitting a number of them to be paralleled across a video line with a minimum disturbance to the driving source. Each amplifier delivers, to a 75 ohm output line, a signal of the same level and polarity as it receives.

When the amplifiers are used to feed several output lines, the inputs being paralleled, there is a high degree of isolation between lines and between any individual line and the source. Thus, disturbances, short circuits, equipment failures, or the like on one line will not be reflected onto the other lines. This is of considerable value to good overall operation in any television installation.

The components of the TA-1A are assembled on a chassis of the recessed, or "bath tub" type. All tubes and other large components are mounted on the front of the chassis, with the resistors and other small components on the rear. This type of construction provides neat appearance, convenient operation and maximum accessibility. The chassis is standard rack width and is designed to mount in either an enclosed cabinet type rack or a standard open type rack. In the latter case a cover panel may be used, if desired.

Each of the five amplifiers consists of two stages. The two tubes and other components which make up each amplifier are arranged in a row across the chassis. Each amplifier is provided with a gain control so that the gain may be varied from approximately .9 to 1.1. This feature is especially convenient when it is desired to equalize accurately the levels on the several output lines.

The input and output connections on the rear of the amplifier are designed to accommodate standard fittings for either RG 11/U or RG 59/U coaxial lines. Two connectors are provided for each input and each output to facilitate interconnecting the sections. This amplifier may be used at any point in a television system regardless of whether the polarity at that point is positive or negative. An adjustment is provided for reducing the low frequency phase distortion to a negligible value.

A built in filament transformer provides filament voltages for all tubes. Plate voltages are obtained externally, preferably from a well regulated power supply such as the Type 580-C. Power connections are made by means of a standard cable receptacle at the lower left of the chassis.

Specifications

Number of Amplifiers	Five
Voltage Gain, Each Amplifier	Adjustable .9 to 1.1
Frequency Char.	±1 db to 10 mc, and adjustable to ideal 60 cycle square-wave response
Input Signal Level (max.)	2 volts, peak-to-peak
Output Signal Level (per section)	2 volts, peak-to-peak
Input Impedance	Bridging
Input Capacity (on two cable sockets)	40 mmf
Input Polarity	Positive or negative
Output Load Impedance	75 ohms
Output Polarity	Positive or negative
Power Supply Required	
a-c 110-120 volts, 60 cycles	50 watts
d-c 280 volts (Type 580-C Supply)	260 ma
Tube Complement	5 RCA 6AC7, 5 RCA 6AG7
Dimensions	12¼" high, 19" wide, 8" deep
Weight	28 lbs.
Stock Identification	MI-26155

Accessories

Tube Kit (complete tube complement)	MI-26676

2J4905-Q

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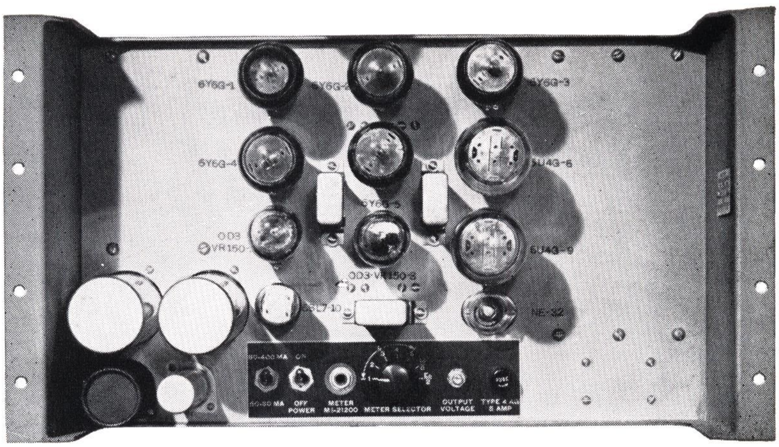
Regulated Power Supply Type 580-C
(General Purpose)



Features

- Extremely well-regulated output.
- Unusually low output ripple.
- Low internal d-c resistance.
- Components and connections easily accessible.
- Compact and neat in arrangement.

Uses

The RCA Type 580-C Regulated Power Supply fills the need for a well-regulated source of d-c at loads of 50 to 400 milliamperes. The output is adjustable between 260 and 295 volts, with variations of less than 0.25 volts from minimum to maximum load. Thus it is suitable for laboratory, industrial, and communications applications in which an unusually well-regulated source of d-c is required. As a-c ripple in the output is less than 0.005 per cent, the output voltage may be used for most purposes without additional filtering.

The Type 580-C is especially suited for use with RCA television equipment, which it matches in appearance and construction.

Description

The regulating circuit employed in the 580-C is of the series type. The d-c internal resistance is less than 0.7 ohms.

This Power Supply is assembled on a recessed chassis of the "bath-tub" type. Tubes and filter condensers project from the front of the chassis, while transformers, resistors, and wiring are at the rear. The chassis is standard rack width and may be mounted either in one of the new enclosed-type RCA cabinet racks, or on a standard "open-face" rack. In the latter event a blank panel may be mounted over the Power Supply if desired. Controls are centralized on a small, plainly-marked panel at the bottom of the unit. In addition to the power "on-off" switch there is provision for switching from a load range of 50-80 ma. to 80-400 ma., as well as a potentiometer for adjusting output voltage. A meter selector switch and a meter jack provide for plugging in a meter to read individual tube plate currents, output current, and output voltage. A special meter (MI-21200-C) is available for this purpose.

Specifications

Output Voltage	Adjustable 260 to 295 volts
Output Current	50 to 400 ma.
D-C Regulation	Less than 0.25 volts, minimum to maximum load
A-C Ripple	Less than 0.005 per cent
Power Supply	110-120 volts, 50-60 cycles
Power Input	370 watts (maximum)

Tube Complement:

2 RCA 0D3/VR150	1 RCA 6SL7GT
2 RCA 5U46	6 RCA 6Y6G
1 NE 32	

Dimensions	10½″ high, 19″ wide, 12″ deep
Weight	58 lbs.

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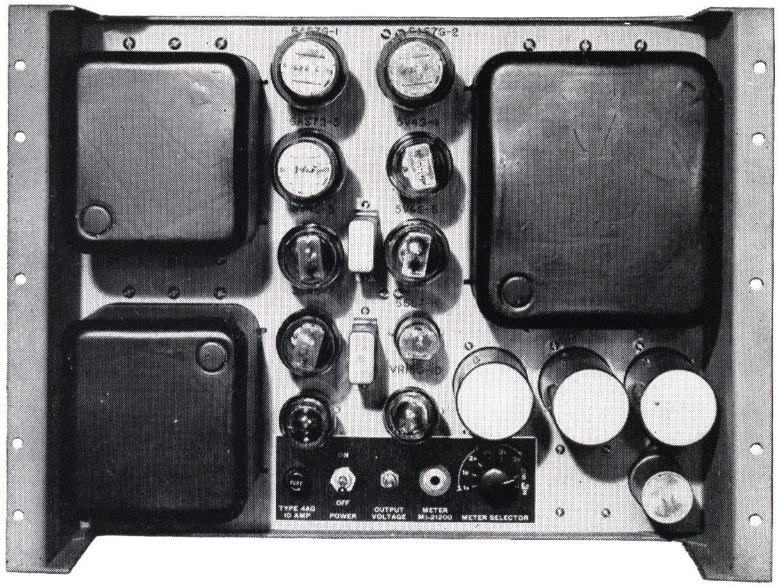
Regulated Power Supply Type WP-33A

(Heavy Duty)



Features

- Extremely well-regulated output.
- Unusually low output ripple.
- Low internal d-c resistance.
- Components and connections easily accessible.
- Kinescope centering-voltage supply included.
- Compact and neat in arrangement.
- Output voltage during starting does no exceed final regulated value.

Uses

The RCA WP-33A Power Supply is intended for laboratory, industrial and communications applications requiring a well-regulated source of d-c voltage at loads of 200 to 600 milliamperes. The output is adjustable between 260 and 295 volts, and varies less than 0.20 volts from minimum to maximum load. A-C ripple in the output is less than 0.005 per cent, so that the output voltage may be used for most purposes without additional filtering.

The Type WP-33A is especially suited for use with RCA television equipment, which it matches in appearance and construction.

Description

The regulating circuit employed in the WP-33A is of the series type. The d-c internal resistance of this Power Supply is less than 0.5 ohms.

The WP-33A is assembled on a recessed chassis of the "bath tub" type. Tubes, filter condensers, and transformers project from the front of the chassis, while transformer terminals, resistors, and wiring are at the rear. The chassis is standard rack width and may be mounted in one of the new enclosed-type RCA cabinet racks or on a standard "open-face" rack. In the latter event, a blank panel may be mounted over the Power Supply if desired.

Controls are centralized on a small, plainly-marked panel at the bottom of the unit. In addition to the power "on-off" switch, there is a potentiometer for adjusting output voltage. A meter selector switch and a meter jack make provision for plugging in a meter to read individual tube plate currents, output current, and output voltage. A special meter (MI-21200-C) is available for this purpose.

Specifications

Output Voltage	Adjustable 260 to 295 volts
Output Current	200 to 600 ma.
D-C Regulation	Less than 0.20 volts, minimum to maximum load
A-C Ripple	Less than 0.005%
Power Supply	105/125 volts, 50/60 cycles
Power Input	450 watts (maximum)

Tube Complement:

4 Type 5V4G	3 Type 6AS7G
1 Type 6SL7GT	2 Type 0D3/VR150

Dimensions	14″ high, 19″ wide, 9″ deep
Weight	82 lbs.

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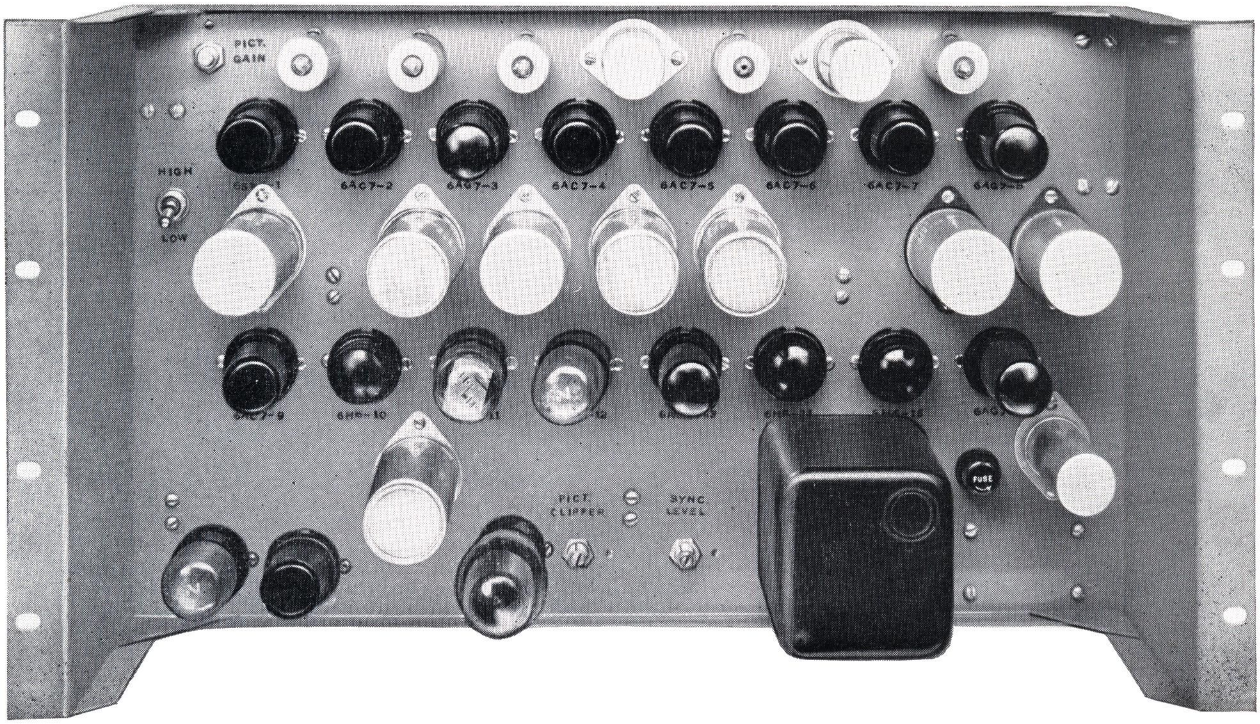
Stabilizing Amplifier Type TA-5B



Features

- Combines sync with video signals; separates sync from video signals.
- Corrects defective video signals, eliminates hum and low-frequency distortion.
- Improves the signal-to-noise ratio of the sync signal.
- Operates on signal levels as low as 0.25 volts peak-to-peak.
- Restores sync to standard 25% levels in signals where sync is as low as 15%.
- For special transmission requirements, can produce 50%, or 1.5 v. of sync.
- Has two identical 75-ohm outputs.
- Power requirements are low.
- Bath tub type chassis mounts on standard rack.
- Remote control available for "Pict. Gain," "Pict. Clipper" and "Sync Level."

Uses

The TA-5B Stabilizing Amplifier is a unit designed to correct, automatically, faulty video television signals which may have become defective in their transmission from the pickup device to the input of the transmitter. It is also used with the RCA Studio Switching Equipment to combine the sync signal with the video signals from the cameras.

The common sources of disturbance in any television system may be classified as follows:

1. Hum or surges originating in power supplies and other random disturbances created by high-impedance grounding circuits, long cable sheaths, etc.
2. Circuit saturation, with resultant destruction of the proper sync-picture ratio.
3. Switching surges, including the shifting of patch cords.
4. Low-frequency distortion introduced by coupling circuits with inadequate time constants.

Elimination of these spurious disturbances at their source is often difficult and sometimes impossible. They must be eliminated, however, because in many cases not only is receiver operation impaired, but proper modulation of the transmitter will be affected. The Stabilizing Amplifier is capable of correcting any one or all of these faults simultaneously, thus producing a signal which is suitable for modulating the transmitter.

Description

The TA-5B Stabilizing Amplifier employs 19 tubes. Nine of these are used in a 6-stage picture amplifier which has two identical output stages for supplying signal to the transmitter and to a picture monitor. The remaining tubes are employed as sync separators, keyers, shapers, clampers, and tubes for adding sync.

A two-position attenuator at the input accommodates a range of input signals from 0.25 volt to 2 volts, peak-to-peak. The output of the amplifier is designed to deliver the standard level of picture and blanking signal (1.5 volts peak-to-peak) with a maximum sync of 1.5 volts peak-to-peak. The amount of sync can be adjusted independently to any value between 0.2 and 1.5 volts, peak-to-peak.

The first three stages provide linear amplification of the incoming signal; while the fourth stage amplifies the sync pulses by a larger factor than it amplifies other parts of the signal. Three tubes are employed in this fourth stage. One operates as a normal amplifier and contributes signal throughout the useful portion of its characteristic curve. The second tube of the trio clamps the black level at a fixed point on the characteristic curve of the third tube, however, so that it operates only at grid levels above the blanking signal, amplifying only the sync signals. Since clamping action is independent of the signal, spurious additive components (at low frequencies) are eliminated from the sync amplifier.

Amplified sync thus passes on to the fifth (clipper) stage of the amplifier which clips off the sync in accordance with its grid bias adjustment, yielding the desired sync-picture ratio at the output of the fifth stage. As is the case in the non-linear amplifier just described, the grid of the clipper is also clamped at black level so that the absolute amplitude of the sync pulses is fixed and independent of variations in the average amplitude of the picture signal. In this stage also, spurious components are eliminated from the picture and blanking portions of the signal.

The sixth and last stage comprises the two output amplifier tubes, one for the transmitter and one for the monitor. The grids of these tubes are in parallel and their plates are coupled separately to two output connectors for 75-ohm coaxial lines. When output higher than the 1.5 volt peak-to-peak is desired, the two outputs can be paralleled to give almost double the signal obtainable from either one alone.

Filament power for all tubes is provided by a transformer mounted on the chassis. Plate voltage must be obtained from an external regulated power supply such as the RCA Type 580-C. All external power connections are made through a 6-pin plug and receptacle. One side of the primary line to the filament transformer is fused.

The TA-5B Stabilizing Amplifier is mounted on a recessed chassis for standard rack-mounting. Therefore, it can be mounted in the transmitter room or studio control room with other rack-mounted equipment

Specifications

Input Signal Voltage
- Min. ________ 0.25 volts, peak-to-peak
- Max. ________ 2.5 volts, peak-to-peak

Permissable Input Signal-to-Noise Ratio
- (a) High-Frequency Noise ________ 2
- (b) Low-Frequency Noise (hum) ________ 1.3

Output Signal Voltage
- (a) Picture and Blanking ________ 1.5 volts, peak-to-peak
- (b) Sync (Max.) ________ 1.5 volts, peak-to-peak

Output Impedance ________ 75 ohms

Frequency Char. ________ ±1 db to 8 mc

Power Requirements
- (a) A-c ________ 100-120 volts, 50/60 cycles, 5 watts, fuse rating, 1 amp.
- (b) D-c ________ 280 volts, 235 ma., regulated (RCA Type 580-C or equivalent)

Dimensions
- Height ________ 10½″
- Width ________ 19″
- Depth ________ 8⅝″

Weight ________ 17 lbs.

Finish (front of chassis) ________ Light umber gray

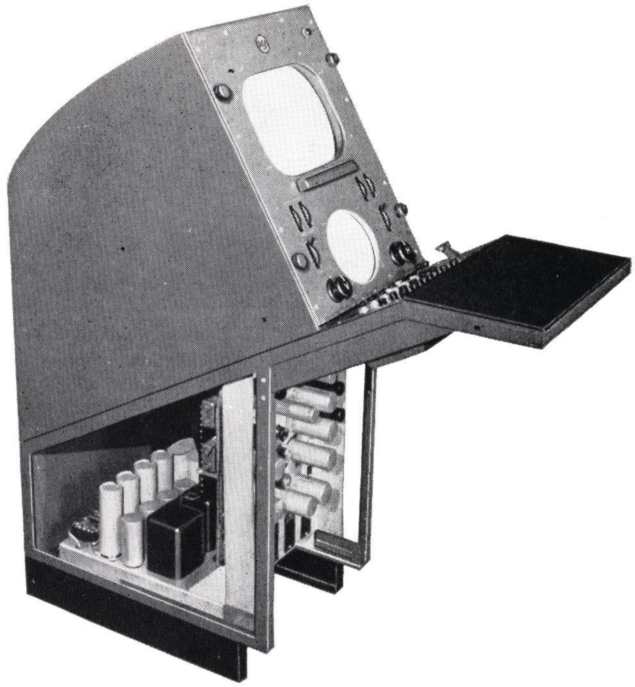
Tube Complement
- 1st Picture Amplifier ________ 1-RCA 6SK7
- 2nd " " ________ 1-RCA 6AC7
- 3rd " " ________ 1-RCA 6AG7
- 4th " " ________ 1-RCA 6AC7
- 5th Picture Amplifier (Sync Clipper) ________ 1-RCA 6AC7
- Picture Clipper ________ 2-RCA 6AC7
- Main Output ________ 1-RCA 6AG7
- Monitor Output ________ 1-RCA 6AG7
- 1st Amplifier—Sync Channel ________ 1-RCA 6AC7
- Sync Separator ________ 1-RCA 6AC7
- Pulse Former ________ 1-RCA 6SN7-GT
- Keying Pulse Driver ________ 1-RCA 6AG7
- Clamp Diodes ________ 3-RCA 6H6
- Sync-Inserter Amplifier ________ 1-RCA 6AC7
- Sync Clipper and Transient Sup. ________ 1-RCA 6SL7-GT
- Voltage Regulator ________ 1-RCA OD3/VR-150

PRINTED IN U.S.A.

Studio Camera Switching Equipment Type TS-10A

Features

- System will accommodate six signal inputs.
- Manual fading control allows choice of any fading speed.
- Remote signals can be previewed before being switched on-the-air.
- Full complement of tally lights.
- Tally lights at on-the-air cameras are activated by the switching system.
- Local sync automatically added when remote sync fails.
- Private or conference communication can be maintained between all stations.
- Intercommunication can be operated with other equipment off.
- All personnel have access to program sound.
- Stabilizing amplifier automatically corrects picture-sync ratio for transmitter.



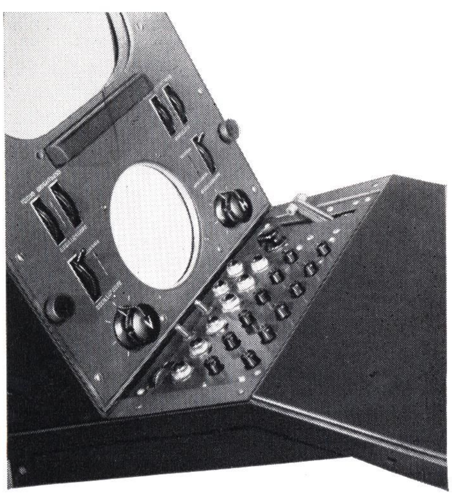
Uses

The TS-10A Studio Camera Switching System is designed for use by television stations obtaining video signals from more than one line. Briefly, the TS-10A will allow a single video operator to do these things: (1) Select any signal from six input lines; (2) switch the desired signal into the on-the-air line; (3) fade or dissolve two signals simultaneously at any speed; (4) fade in or fade out any one signal; (5) switch instantaneously from one signal to another; and (6) superimpose two signals with any desired degree of magnitude for each signal.

Intercommunication circuits in the TS-10A allow program personnel two-way conversation. In addition, volume-controlled program sound is supplied to all personnel through one earpiece of their headset.

Description

The TS-10A Studio Camera Switching Equipment consists of the switching amplifier chassis-type unit, a TM-5A Master Monitor, two WP-33A Power Supplies and a TA-5B Stabilizing Amplifier. The switching amplifier is mounted in the lower compartment of an RCA desk-type console section, and the TM-5A Master Monitor is mounted above it. The TA-5B Stabilizing Amplifier and WP-33A Power Supplies are also chassis-type units designed for mounting in a standard equipment rack.



Close-up of TS-10A Control Panel

The controls for the switching amplifier project through the inclined top panel of the desk. These controls consist of two banks of pushbuttons from which the on-the-air signal is selected, two toggle switches for controlling local and remote sync, gain controls for two remote input lines, a three-position switch for selecting either the on-the-air signal or one of the two remote signals for preview display on the monitor, fading and dissolving controls, and tally lights showing which inputs are being used.

The switching amplifier consists of 3 two-stage picture amplifiers and 2 two-stage sync relay interlock amplifiers. Two of the picture amplifiers have their inputs connected to separate banks of camera selector switches. They have common outputs, however, so that they can serve one camera singly or two cameras together in a lap-dissolve or superimposition. The third picture amplifier feeds the monitor input. The two sync amplifiers automatically add local sync to the video signal when remote sync fails or when local sync is otherwise required.

Specifications

Power Line Requirements
100-120 volts, 50/60 cycles, 1060 (max.) watts
(includes power required by the two WP-33A Power Supplies)

Input Signal:
- Local Input (video from camera control) .... 1.5 v. peak-to-peak
- Auxiliary Input (as remote) .... 1.5 v. min. peak-to-peak video, 18-33% sync

Input Impedance:
- Local Input .... 75 ohms
- Auxiliary Input (as remote) .... 75 ohms, variable line termination

Output Impedance .... 75 ohms

Mechanical Specifications (Console Section):
- Dimensions (overall) .... 41" High, 13" Wide, 6" Deep
- Weight .... 46 lbs.
- Finish .... Dark umber gray

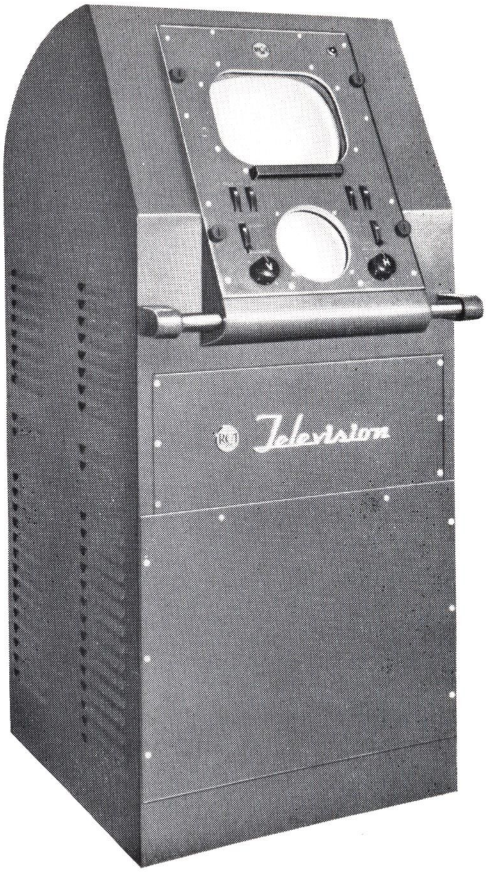
2J4905-U

PRINTED IN U.S.A.

Portable Monitor Type TM-15A

Features

- Cabinet requires minimum floor space.
- Rubber-tired wheels assure quiet, easy movement from place to place.
- Inclined panel is at convenient height for observation from standing position.
- Monitor operates with synchronized picture input, or with separate video signal inputs.
- Video waveforms can be displayed and component voltages measured.



Uses

The Portable Monitor consists of a chassis-type TM-5A Master Monitor and WP-33A Regulated Power Supply mounted in an upright cabinet fitted with rubber-tired wheels. The portable monitor can be wheeled about the television control room or transmitter room and connected to various points in the video circuit to obtain a large bright picture of the video signal.

IN THE STUDIO CONTROL ROOM, the Portable Monitor is a valuable adjunct to the monitors in the video console. It enables operating personnel to observe the composite video signal at points along the program line which are not wired into the console. Or, in station layouts where few console monitors are employed, the Portable Monitor may be cut in at various points to observe the picture without the need for switching monitors from circuits requiring continuous observation.

IN THE TRANSMITTER ROOM, the monitor in the transmitter console can be switched to the input of the transmitter, the output of the modulator, or the output of the transmitter (if a picture demodulator is used). However, by use of the Portable Monitor, the signal can be monitored at one point while the console monitor is simultaneously reproducing the signal obtained at another. Thus, accurate comparisons can be made of the reproduced signal at various stages of its transmission. The Portable Monitor is also useful in monitoring signals at rack-mounted units such as the relay receiver, stabilizing amplifier, distribution amplifier, monoscope camera, etc.

Description

The cabinet is of convenient height for the operator to observe from a standing position the picture appearing on the screen at the top of the inclined panel. All controls for the monitor are easily accessible on this panel, and a 5-inch oscilloscope screen at the bottom of the panel permits the operator to make amplitude measurements of components of the picture signal. Ample space in the bottom compartment of the cabinet is provided for mounting the WP-33A Regulated Power Supply which furnishes plate and screen voltages for the monitor circuits.

Input circuits of the Monitor can be permanently wired into selected points in the circuits, or fitted with a flexible cable with test probes for picking up the video signal at any number of points. Combinations of these two methods are also possible.

Specifications

Frequency Response:
- Kinescope Amplifier .... ±1 db to 6 mc
- Oscilloscope Amplifier .... Down 6 db. at 4½ mc

Input Impedance:
- Kinescope Input .... High
- Oscilloscope Input .... High

Signal Input Range:
- Kinescope Input .... 0.75 to 3.0 volts
- Oscilloscope Input .... 0.75 to 3.0 volts

Power Required:
- 105-125 volts, 60 cycle, single phase .... 250 watts
  (280 volt d-c plate and —7 volt d-c centering voltages are obtained from the WP-33A Power Supply which requires 450 watts).

Dimensions Overall .... 49⅛" high, 21" wide, 28¼" deep

Weight .... 310 lbs.

Tubes Required (Monitor Chassis):

1 RCA-5CP1-A	10 RCA-6SN7GT
1 RCA-1816P4	1 RCA-6SL7
3 RCA-6AC7	2 RCA-6BG6-G
6 RCA-6AG7	1 RCA-6AS7G
2 RCA-6AL5	2 RCA-1B3GT/8016

2J4905-V

PRINTED IN U.S.A.

Television Relay Transmitter Type TTR-1B

Features

- Complete transmitting system.
- Suitable for permanent installation.
- Completely portable for field pickups.
- Superfrequency operation permits simplified circuits and small physical size.
- Flexibility of operation.
- Lightweight.
- Optional console operation.
- Highly directional antenna.

Uses

The Type TTR-1B Relay Transmitter, when used with a Type TRR-1A Relay Receiver, constitutes a highly directional wide-band relay link especially suited to the transmission of television video signals. Such a link circuit has two important applications which are:

(a) FOR STUDIO-TO-TRANSMITTER CIRCUITS where conditions of terrain, distance, or right-of-way make it more convenient or economical than a coaxial line. For such use the transmitter and parabolic antenna units will be permanently mounted on the roof or other high location near the studio and the transmitter control unit will be mounted, ordinarily, on the equipment racks in the studio control room. The receiving equipment will be permanently located at the transmitter site.

(b) FOR FIELD PICKUPS as a means of transmitting the video signal back to the studio when no coaxial line or satisfactory wire line is available for the purpose. In this case, the rotatable tripod mounting illustrated will ordinarily be used. The antenna will be located on some high point, such as the top of a stadium where there is a line-of-sight path to the receiving antenna at the studio. The transmitter control unit will be located with the camera control equipment as, for instance, in the radio booth or in the field truck or mobile unit.

Description

The TTR-1B Relay Transmitter is a complete, transportable transmitting system consisting of (1) a transmitter, (2) a highly directional antenna, (3) a rotatable antenna mounting unit, and (4) a transmitter control unit. These units are designed to work together, and may easily be set up and connected by means of plug-in cables.

The transmitter is contained in a cylindrical weatherproof housing attached to the rear of a parabolic reflector. It utilizes a klystron oscillator which is frequency-modulated by variations of the negative voltage on the repeller plate. It has a power output of approximately 100 milliwatts, operating at any selected frequency between 6500 and 7050 megacycles. The normal frequency deviation is 12 mc. with polarity such that a video signal in the white direction produces an increase in frequency. The output is fed to the parabolic reflector by means of a wave guide. Coupled into this wave guide system are an absorption type wavemeter, and a crystal detector monitor. The wavemeter is preset to any desired frequency. The d-c from the crystal detector may be measured either at the transmitter or at the transmitter control unit as a rough indication of relative power output. The a-c component of the crystal detector output is amplified and fed over a coaxial line to the transmitter control unit where it serves during preliminary adjustment to indicate the correct frequency, and during operation, to indicate proper centering of the signal around the resonant frequency of the klystron cavity. Filament power for the tubes in the transmitter is supplied from a small filament transformer on the same chassis. All other voltage supplies are received on the transmitter chassis which are accessible by removing the protective cover over the cable input connection. By plugging in a suitable meter in the proper jack, it is possible to measure the current through modulator tube, and the oscillator tube. Another jack is provided so that a telephone handset can be plugged into the unit for communication with the transmitter control unit location.

The parabolic antenna provides a very high gain in the direction of transmission. The four foot size (illustrated) has a gain of approximately 5000, thereby giving an equivalent power output of 500 watts. The parabola is also available in the six foot size, with approximately twice the gain, for use in communicating over greater distances. Transmission is limited to a line-of-sight path, and under normal conditions, a range of 10 to 15 miles may be expected with a satisfactory signal to noise ratio.

The antenna and transmitter are mounted on a standard rotatable camera tripod mounting unit. This mounting unit may be accurately adjusted over wide vertical and horizontal angles. For fixed installations, a different type of mounting, providing only small adjustments of angle, is available.

The transmitter control unit is housed in a small, easily-carried, portable cabinet with a convenient handle on the top. The controls are accessibly located on a control panel on the side of the cabinet. This control unit may be located up to 400 feet away from the transmitter. It contains all the necessary operating and monitoring controls, and after initial adjustments of the transmitter and antenna have been made, all operations may be carried on from this unit. It also contains a regulated B+ supply for operation of the transmitter tubes, and a regulated negative supply for the klystron repeller plate. For greater operating convenience, provision is made for extending the operation of the controls necessary for routine adjustments of the transmitter to a monitoring console.

Specifications

Frequency Range — 6800-7050 mc.
Power Output — 100 milliwatts
Antenna Gain
- 4 ft. reflector — 4,500
- 6 ft. reflector — 10,000

Frequency Deviation for 100% Modulation — 10 mc.
Video Input Impedance — 75 ohms
Video Frequency Range — 60 cycles to 6 mc.
FM Noise Level Below ±10 mc Swing — —32 db
AM Noise Level Below (Maximum) Modulation — —40 db
Power Supply Requirements:
- 110 volt, 60 cycles a-c — 150 watts

Tube Complement:

Transmitter

1—6AG7	1—6H6
2—6SL7GT	1—2K26

Transmitter Control Unit

1—6AG7	1—5V4G
2—6X5GT	1—6AS7G
4—VR150	1—6SL7GT

Reflector Dimensions:	*Diameter*	*Focal Length*	*Depth*
	4′	14.5″	10″
	6′	21″	14″

Transmitter — 13″ Diameter, 17″ Long
Transmitter Control Unit:
- Carrying Case — 20″ Long, 19″ High, 13″ Wide
- Standard Rack Space — 10½″

Finish — Two-tone umber grey
Weights:
- Transmitter and Housing — 26 lbs.
- Transmitter Control Unit — 38 lbs.

Stock Identification — MI-26935

2J4905-W

PRINTED IN U.S.A.

Television Relay Receiver Type TRR-1B

Features

- Complete receiving system.
- Suitable for permanent installation.
- Completely portable for field use.
- Lightweight.
- Optional console operation.
- Effective automatic frequency control.

Uses

The Type TRR-1B Relay Receiver, when used with a Type TTR-1B Relay Transmitter, constitutes a highly-directional wide-band radio link especially suited to the transmission and reception of television video signals. Such a link circuit has two important applications which are:

(a) FOR STUDIO-TO-TRANSMITTER CIRCUITS where conditions of terrain, distance, or right-of-way make such a system more convenient or economical than a coaxial line. For such use the antenna of the TRR-1B is located on a tower or other high point near the transmitter building in a fixed position directed toward the TTR-1B Transmitter located at the studio. The receiver control unit and power supply unit are ordinarily mounted on equipment racks in the transmitter control room.

(b) FOR FIELD PICKUPS where a TTR-1B Transmitter, arranged for portable use, is employed to send the video signal back to the studio (instead of wire or coaxial lines). In this case a rotatable mounting such as that illustrated will ordinarily be used (since there will be pickups from various directions). For temporary use, the tripod mounting may be used. When the equipment is used frequently, a more permanent mounting is desirable. In any event it must be high enough to provide a line-of-sight path to the transmitting antenna location.

Description

The TRR-1B Relay Receiver is a complete (transportable, if desired) FM receiving system covering of frequency range of 6500-7050 megacycles. It consists of (1) a receiver, (2) a highly directional antenna, (3) an antenna mounting unit which may be either fixed or rotatable, (4) a receiver control unit, and (5) a regulated power supply unit. These units are easily set up and connected by means of convenient plug-in cables.

The signal is picked up on the highly directional, high gain (4500) parabolic antenna and fed into the receiver. The receiver is contained in a cylindrical, weatherproof housing attached to the back of the parabolic reflector. This housing contains a klystron tube heterodyne oscillator, a crystal mixer circuit, and five stages of the receiver i-f amplifier. This provides an output signal of about 50 millivolts at an i-f center frequency of 120 mc. This signal is fed to a coaxial line leading to the receiver control unit. The receiver has a built-in transformer which supplies filament power to all tubes. All other voltages are obtained from the power supply by way of the receiver control unit. The equipment is provided with an intercommunication system so that handsets may be plugged in and operators may communicate between the receiver and the receiver control unit.

The receiver control unit contains seven additional i-f stages, the limiter and discriminator stages, and the AFC system. There are two separate discriminator channels fed from the output of the i-f amplifier. One supplies signal to the main transmitter and monitoring circuits. The other is used to generate a control voltage for the AFC amplifier. The purpose of the AFC is to control the frequency of the heterodyne oscillator and keep it in proper adjustment for variations in transmitter frequency. The receiver control unit is connected to the receiver by means of a single cable with plug connectors at each end. In operation this cable may be as long as 200 feet. For special cases, however, it may be made as long as 1000 feet by employing a separate coaxial line carrying the i-f signal. In addition, a cable connector at the rear of the receiver control unit permits the connection of an extension cable so that routine operation may be conducted from a nearby monitoring console. Both this unit and the power supply are intended to be mounted in a standard equipment rack, as illustrated. A small control panel is located on the front from which all adjustments can be made. They may also be mounted in convenient carrying cases for portable operation, if desired. This unit has its own filament transformer, but the other voltages are received from the power supply. All tubes are accessible from the front of the unit, and all cable connections are made at the rear.

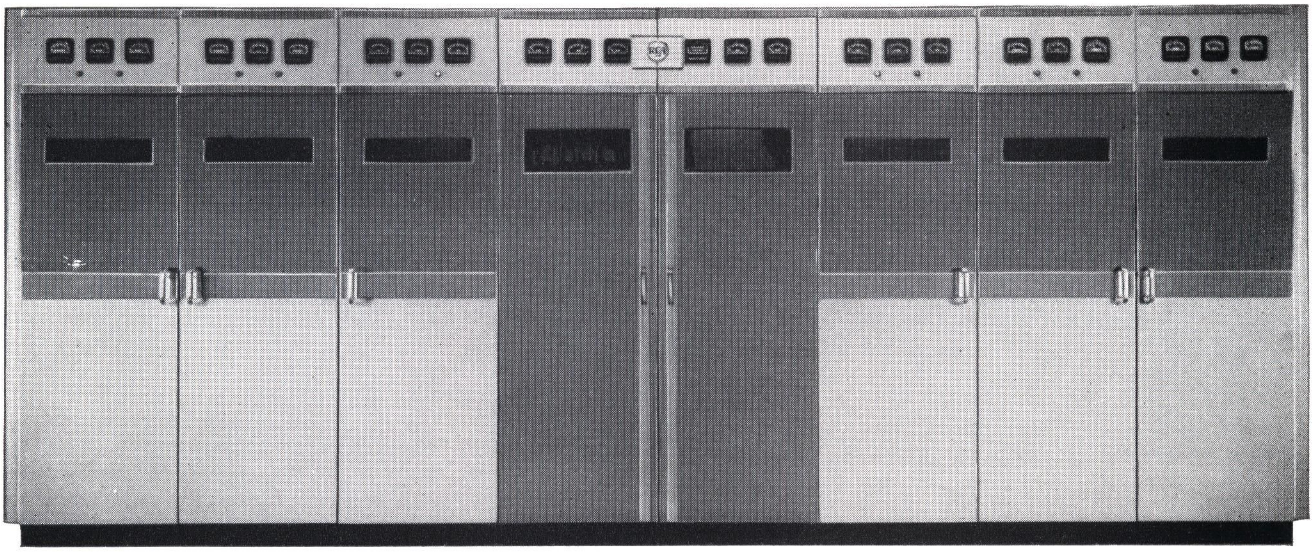
Specifications

Frequency Range	6800-7050 mc.
Type of Reception	Frequency modulation
Video Frequency Range	60 cycles to 6 mc.
Band Width	15 mc.
Tube Complement:	
Receiver	1—2K26 1—6J6 4—6AK5
Receiver Control Unit	11—6AK5, 3—6J6, 2—6AL5, 1—6AC7, 2—6AG7, 2—6SL7-GT, 1—6SN7-GT
Total Power Consumption	110 volts, 60 cycles a-c, 250 watts
Weights:	
Receiver and Housing	35 lbs.
Receiver Control	36 lbs.
Power Supply	58 lbs.
Stock Identification	MI-26940

2J4905-X

PRINTED IN U.S.A.

Television Transmitter Type TT-5A



Features

- Low installation costs—flexible cabinet arrangement.
- Low operating cost.
- Uses highly efficient RCA 8D21 dual tetrode as power amplifier.
- Power amplifiers require no neutralization.
- Quick changing of power amplifier tubes.
- High level modulation in visual section.
- Straight-forward "meter tuning" of all r-f driver stages.
- Uses highly efficient RCA FM exciter in aural section.
- Packaged for convenience in shipping and installation.
- All components readily accessible through front and rear doors.

Description

The TT-5A is RCA's first post-war television transmitter. It represents the culmination of the many years of RCA Television research and development. Many new features found in this transmitter are the first applications of the latest RCA developments.

The transmitter has a nominal power output of five kilowatts peak visual power, and two and one-half kilowatts peak aural power. This ratio is in conformance with the RMA standard. The frequency range is from 54 to 216 mc., which covers the twelve presently assigned television channels for metropolitan operation.

The entire transmitter is housed in eight steel cabinets which are fastened to a base frame. This frame is divided in such a manner that the eight cabinets may be placed either in a straight line (overall width—208″) or in a "U"-shaped arrangement (smallest possible overall width—150″). Each cabinet has both a front and rear door. The front doors are provided with windows for observing the transmitter while in operation. The components and wiring are arranged to permit maximum accessibility, for testing and servicing. End trim and meter panels complete the cabinet enclosure, so that it presents a pleasing and dignified appearance. A filtered air supply for each cabinet is provided through individual removable filters in the bottom. Warm air is expelled through the top. The visual section of the transmitter is located on the right side and the aural section is on the left, with the power supplies and control panel for both sections in the center. This central location of power controls provides a high degree of convenience and flexibility in the operation of the transmitter.

The transmitter control circuits employ the newest and most modern techniques. Provision is made for both manual and automatic-sequence starting. The automatic system provides a three shot recycling sequence, which automatically returns the transmitter to the air up to three times in case of momentary overload. If the overload persists, the transmitter is automatically shut down. A special hold-in circuit permits the transmitter to return instantly to the air in the case of momentary power line failure, thus avoiding the thirty second delay required for the plate time-delay relay to close. A switch is provided for each main rectifier to provide a reduced power position for tune-up and emergency operation. All critical power supplies are electronically regulated, making possible stable, high-quality operation under all conditions of signal or line voltage variation.

The visual section of the transmitter is essentially a crystal oscillator followed by several r-f amplifier stages, and a grid-modulated, power amplifier. The use of final-amplifier, grid-moduation makes possible the operation of all driver stages as high-efficiency, narrow-band, class "C" amplifiers, which can be tuned quickly and easily from front panel meter observations.

The final power stage uses the new RCA 8D21 water-cooled dual tetrode operated as a push pull amplifier. The use of this tube is one of the outstanding features of this transmitter. Its highly efficient water cooling system introduces a new principle in tube construction which permits roughly ten times the power handling capacity of other tubes of comparable size. It results in exceptionally low output capacitance. This, together with the dual tetrode construction does away with the necessity of neutralization. Since small physical size and low output capacitance are necessary requirements for broad band operation at television frequencies, this tube is an important development in the progress of television.

The aural section of the transmitter utilizes the highly efficient RCA FM exciter, MI-7015, followed by several amplifier stages, and a power amplifier likewise employing the RCA 8D21 dual tetrode.

Coupled into the outputs of both the visual and aural sections of the transmitter are "Reflectometer" units, which perform the following important functions:

1. Measure the standing wave ratio on the main transmission line.
2. Measure the "Peak of Sync" power output (when calibrated against the dummy load).
3. Operate as an r-f overvoltage output, thus protecting the transmission line against rupture due to lightning, bad instrumentation or any trouble which causes excessive standing waves to occur.

The power circuits are so arranged that the operator may do emergency maintenance or servicing work on the aural or visual section of the transmitter while the other is on the air. This includes changing the 8D21 tubes without shutting down the water circulator. The operator is fully protected by proper interlocking and safety devices. During test periods, either section of the transmitter may be operated independent of the other with a resultant saving in overall power consumption.

All high power circuits are doubly protected by highspeed overload relays backed up by thermal type circuit breaker switches. Similar circuit breaker type switches are used to connect water cooler, blowers, filaments, and low power circuits to the power line. All fuses are of the visual indicating type, and are mounted in a group on the front panel for easy accessibility and identification.

In order to provide greater convenience in shipping and installation, the transmitter is partially disassembled when it leaves the factory. The largest unit, uncrated, is 25 x 38 x 80 inches, and no single unit weighs over 1000 pounds. This facilitates handling in confined spaces and elevators. All connections between units are made from conveniently located terminal boards on each unit.

Specifications

	Aural	*Visual*
Type of emision	A3	A5
Frequency range	Chan. 2 to 13	Chan. 2 to 13
Power output (into transmission line)	2 to 4 kw.	2.5 to 5 kw peak
RF output impedance	72 ohms	72 ohms
Carrier frequency stability	±0.002%	±0.002%
Modulation capability	±50 kc.	90%
Method of modulation	Frequency mod.	Amplitude mod.
Input impedance	600 ohms	75 ohms
Input level	+12, ±2 db	1 volt peak to peak
Frequency response**	Uniform within ±1 db from 30 to 15,000 cycles	*0 db at 0.1 mc. 2 db at 0.5 mc. 2 db at 1.25 mc. 2 db at 2 mc. 2 db at 3 mc. 3 db at 4 mc.
Audio frequency distortion:***		
50 to 100 cycles	1.5%	
100 to 7,500 cycles	1.0%	
7,500 to 15,000 cycles	1.5%	
Noise level:		
FM noise, below ±25 kc swing	60 db	
Amplitude noise, rms below carrier	50 db	
Amplitude variation over one frame.		Less than 5% of peak to peak signal amplitude

Power Line Requirement:

Transmitter

Line voltage	208/230 volts
Phase	3
Frequency	50 or 60 cycles
Instantaneous regulation	5% maximum
Power consumption (approx.)	32 kw
Power factor	85%

Console, crystal heaters, etc.

Line voltage	115 volts
Phase	1
Frequency	50 or 60 cycles
Power consumption (approx.)	600 watts

Dimensions:

Overall length****	208"
Overall height	84"
Overall depth (inc. door handles)	38"
Building entrance and elevator clearance requirements	25" x 80"

Weight:

Transmitter**** (8 cabinets plus 2 PA cabinets)	8000 lbs. (approx.)
Console	600 lbs. (approx.)
Water circulating system	1300 lbs. (approx.)

Finish — Two-tone umber gray with satin chrome trim and fittings

Stock Identification — MI-19205-A, B

* Maximum attenuation with respect to idealized rectified vestigial sideband response.

** For pre-emphasized response the pre-emphasis filter (MI-4926A) is provided to be inserted in the 600 ohm audio input line at the most effective point.

*** Distortion and noise are measured following a standard de-emphasis network.

**** To facilitate packaging and handling, the equipment breaks down into its component cabinets (8 plus 2 PA cabinets) and is shipped accordingly. The larger power supply components are also removed and packed separately. Thus, the dimensions of the largest unit (unpacked) is 25 x 80 x 38 inches, and the weight approximately 600 lbs.

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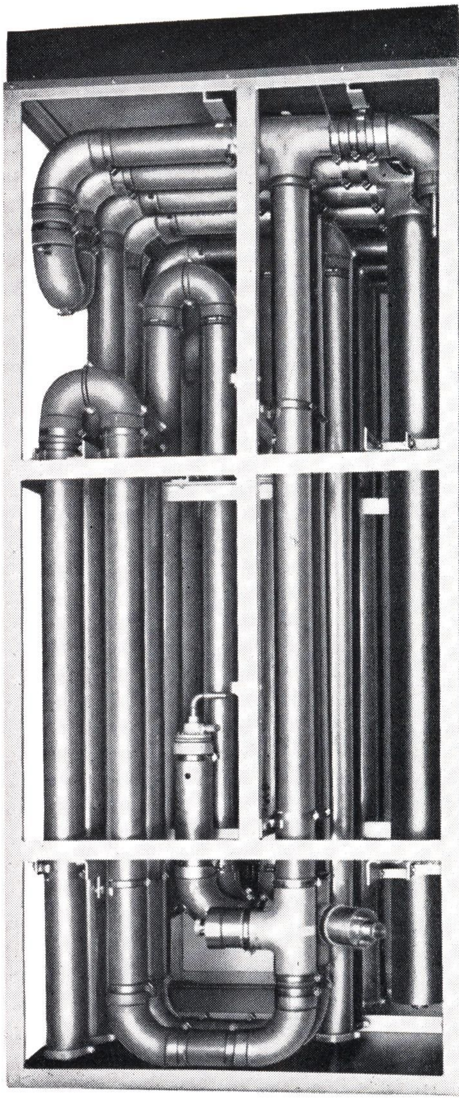
Vestigial Side Band Filter Type TZ-1A

Features

- Small size—small floor space.
- No adjustments.
- Low insertion loss.
- Constant impedance input over entire double sideband.
- Completely enclosed to prevent tampering and admission of dust.



Description

The sideband filter is a device which is connected directly to the output of the television visual transmitter to absorb the relatively small amount of lower sideband energy falling outside of the assigned television channel. Use of a sideband filter has several advantages: first, the tedious adjustment of tuned radio frequency amplifiers needed for the rejection of the sideband when low level modulation is employed is eliminated; second, the sideband filter has a constant impedance input so that the process of sideband elimination is accomplished without a detrimental effect on the picture quality; and third, the high level modulation system used in the transmitter gives the visual transmitter a better overall linearity.

Electrically, the sideband filter is a combination of two M-derived filters. Since filter components of the common coil and condenser construction would be difficult to manufacture and uneconomical to use because of the currents, voltages and reactances involved, the sideband filter has been designed, using low loss coaxial transmission line elements. The undesired sidebands are passed through one of the filter units into a properly terminated transmission line that effectively eliminates reflections of the lower sidebands. The desired signals are passed through the other filter unit and a notch filter. The notch filter is incorporated in the design to give positive insurance against interference with the sound channel of the next lower television channel. This notch filter is a system of resonant coaxial transmission line elements that allows the absorption of a single frequency in a second terminated coaxial transmission line while the desired television signals are not effected.

Since the filter is completely assembled at the factory, all tuning adjustments are factory made. It is contained in a completely enclosed metal cabinet finished in umber-gray and styled to match the associated television transmitter. The sideband filter is designed to stand in a vertical position near the visual transmitter, with a connecting transmission line preferably not more than 10 feet in length. The transmission line connecting the filter to the visual transmitter may leave the filter through the top or bottom or on one side. The output line passes through the top of the unit. The only other connections are with the station water-cooling supply and the visual transmitter interlock circuit.

Vestigial sideband filter, MI-19104-A, covers channels 1 to 6 inclusive; and vestigial sideband filter, MI-19104-B covers channels 7 to 13 inclusive. Each unit is tuned for the desired specific channel at the factory.

Specifications

Dimensions
- Height* .... 84″
- Width .... 36″
- Depth .... 42″

Weight .... 1400 lbs.

Finish .... Two-tone umber gray

Water connections (connected to transmitter water cooling system)
- "In" union for ½ nominal dia. copper water tubing
- "Out" union for ½ nominal dia. copper water tubing

Electrical Connections .... Transmitter interlock of circuit

Radio Frequency Connections
- Input Impedance .... 72 ohms, 3⅛″ coaxial line
- Output Impedance .... 72 ohms, 3⅛″ coaxial line

* Height of sideband filter with base taken off for shipment is 80″.

2J4905-Z

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Television Diplexer Units Type TX-2A

Features

- Permits use of one antenna for both visual and aural television signals.
- Enclosed cabinet prevents tampering and admission of dust.
- Cabinet sides easily removed for inspection.
- Dependable. Electrical networks are composed of conservatively rated coaxial sections.
- No adjustment required at installation.
- Occupies little floor space.

Description

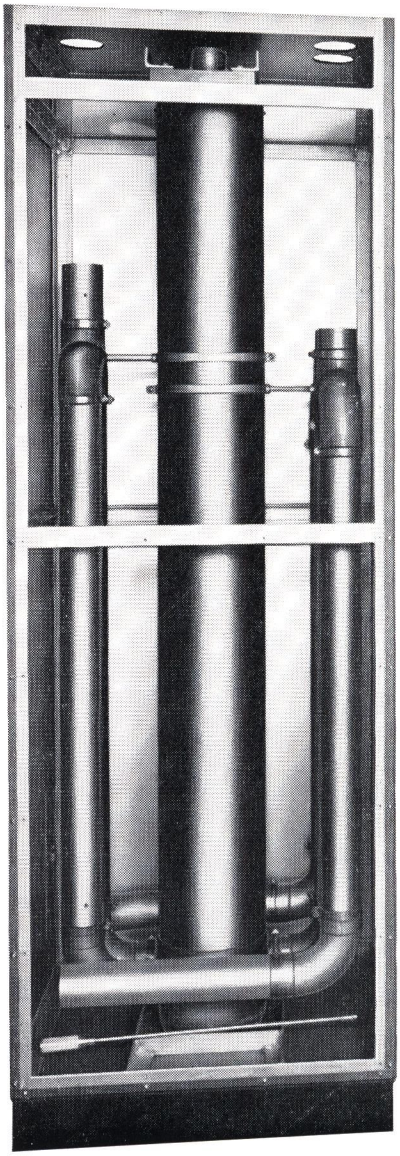
The Television Diplexer is a device to permit the feeding of both the telvision visual signal and the television aural signal to the same turnstile antenna without detrimental cross talk. This eliminates one of the two transmitting antennas that would otherwise be required and thereby saves the expense of an additional antenna with its associated supporting tower.

There are two types of Television Diplexers: one for low frequencies and one for high frequencies. MI-19021 covers the television channels 1 through 6, and MI-19022 covers channels 7 through 13. The low frequency diplexer is larger than the high frequency unit because of the greater physical size of the components.

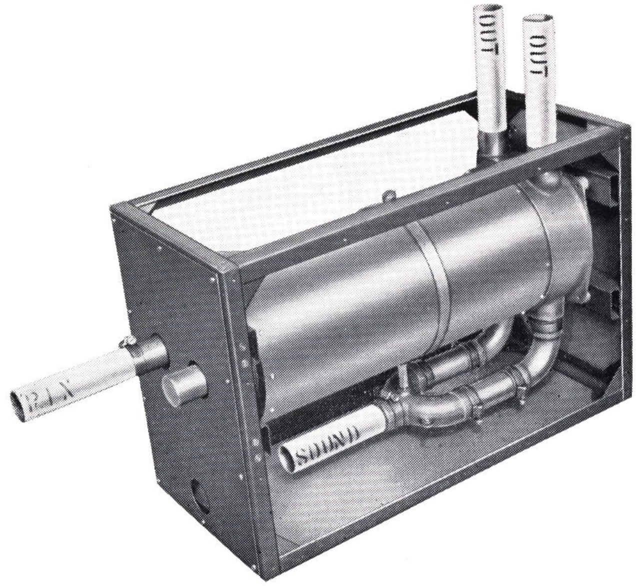
The diplexers are completely enclosed in steel cabinets finished in umber-gray, and styled to match the apparatus with which they are associated. The cabinet sides are easily removed for routine inspection. The unit is shipped complete, and no adjustment is required during installation.

In a simplified form, the diplexer may be considered to be a balanced bridge circuit in which there are four legs, as illustrated in the accompanying diagram. The visual and the aural signals are fed to alternate diagonals of the bridge. Since the aural signal is fed into the circuit across the mid-points of the antenna and the reactors, no visual signal can go into the aural transmitter. In like manner, the visual signal is fed to the circuit between two points of equal potential with respect to the aural transmitter so that no aural signal can get back to the visual transmitter.

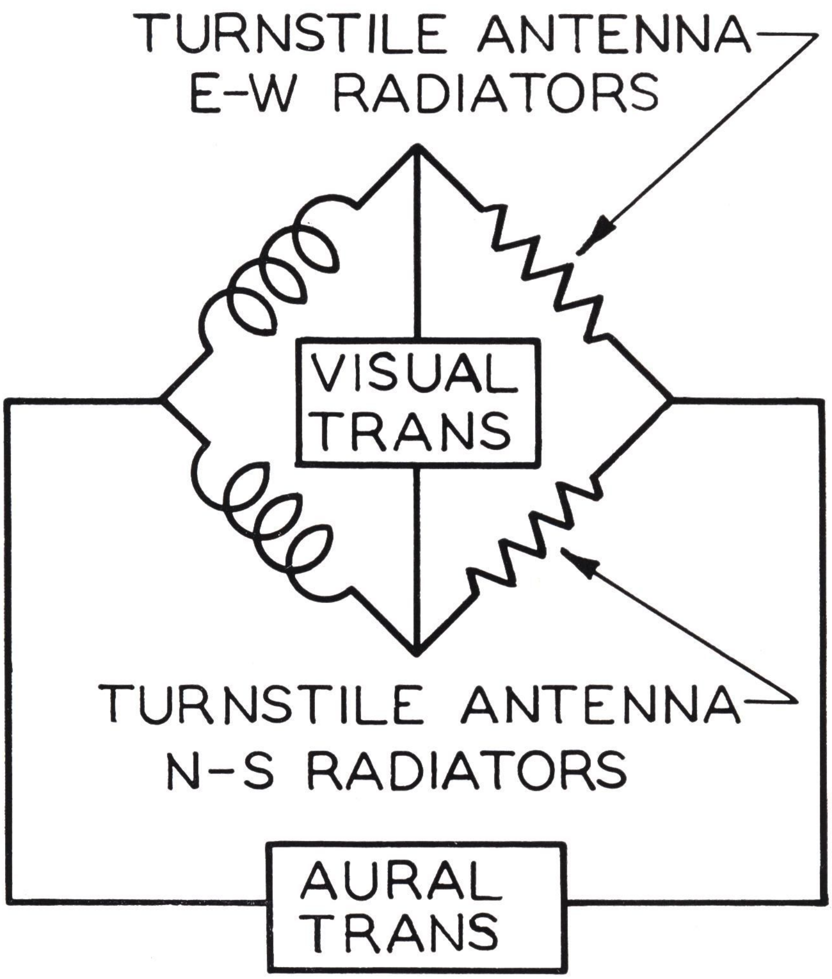
The Television Diplexer is installed in the station room, as near as possible to the vestigial sideband filter. In this way, it is convenient for inspection and maintenance, and no wind or weight load is added to the tower. Because of the upright cabinet type of construction, it occupies very little station floor space.



Low-frequency Diplexer, MI-19021



High-frequency Diplexer, MI-19022



Simplified Schematic Diagram of Television Diplexer Unit

Specifications

LOW FREQUENCY DIPLEXER MI-19021

Dimensions	
Height	84″
Width	28⅛″
Depth	22⅝″
Weight	450 lbs.
Finish	Umber gray
Radio Frequency Connections:	
Input	
Visual	72 ohms, 3⅛″ coaxial line
Aural	72 ohms, 3⅛″ coaxial line
Output	
Two	51.5 ohms, 3⅛″ coaxial line
Cross Talk	Below 40 db.

HIGH FREQUENCY DIPLEXER MI-19022

Dimensions	
Height	17″
Width	11″
Depth	26⅜″
Weight	110 lbs.
Finish	Umber gray
Radio Frequency Connections:	
Input	
Visual	72 ohms, 1⅝″ coaxial line
Aural	72 ohms, 1⅝″ coaxial line
Output	
Two	51.5 ohms, 1⅝″ coaxial line
Cross Talk	Below 40 db.

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Television Triplexer Type TX-3A

Features

- Permits use of one Super Turnstile antenna for both FM and TV services.
- Styled to match other transmitting equipment.
- Simple, compact design.
- Requires no elaborate accessory items.
- Small floor space requirement.

Uses

The RCA Triplexer is designed to permit feeding three independent signals to the Super Turnstile Antenna from where they can be radiated with good efficiency. The need for such a system might be found by the broadcaster planning television plus FM service. In this case all three, FM signals in the 88-108 mc band, the TV picture signal and the TV sound signal can be fed through the Triplexer to one Super Turnstile Antenna, saving the broadcaster the expense of separate antennas. The broadband characteristics of the Super Turnstile make such a system very practicable.

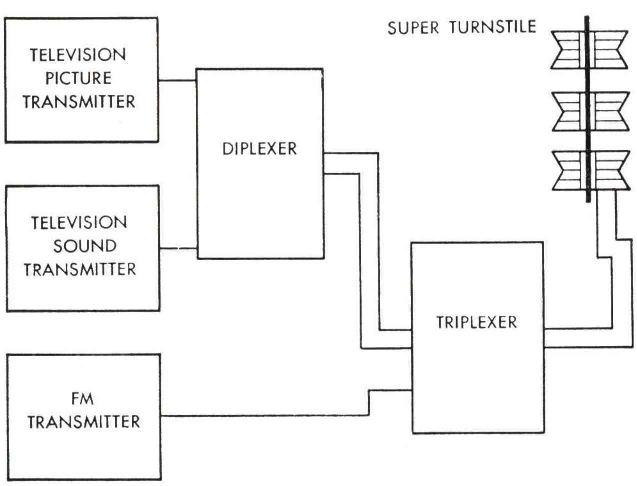
Description

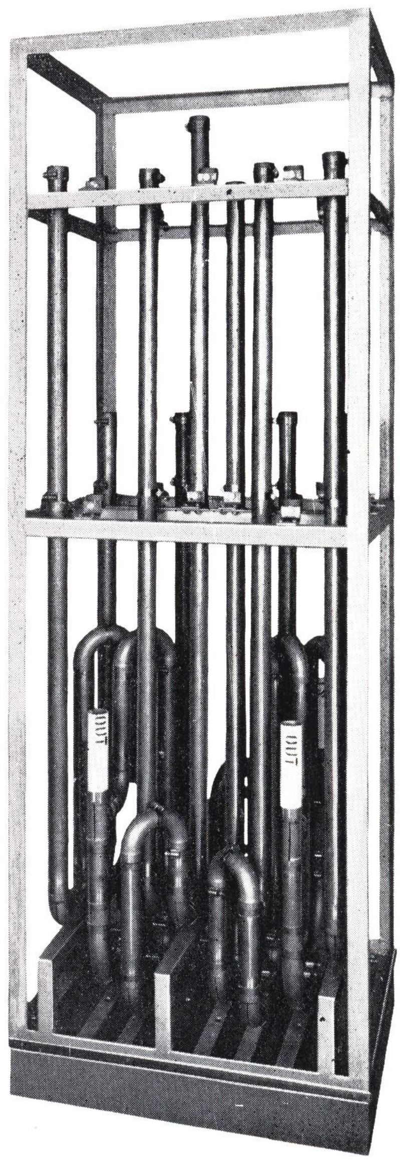
The Triplexer consists of a number of rigid coaxial line segments tuned to the frequencies of the three signals fed into it. These tuned segments act as wave traps to prevent any one of the three signals from feeding back into the feed lines of the other two.

The usual arrangement is to have the TV picture and sound transmitters feed through a Diplexer to the Triplexer. The FM signal is fed directly to the Triplexer as shown in the diagram.

The FM power that can be handled by this system is limited by the standing wave ratios appearing on the lines. This is, of course, determined by the operating frequencies used. In general, the following combinations apply: TV channels II and III with an FM input up to 3 kw; channels IV-VI with an FM input up to 10 kw; and channels VII-XIII with an FM input up to 3 kw.

The coaxial line assembly of the Triplexer is contained in a completely enclosed steel cabinet the same size as the standard low-frequency Diplexer unit. The Triplexer, which is installed adjacent to the Diplexer, is finished in umber-gray to match the other television units.





Triplexer with all covers removed to show system of tunable coaxial lines. Two output connectors are made near the bottom, as shown. The two input lines are at the rear and are not visible.

Specifications

Input and Output Impedances	51½ ohms
Height	84″
Width	22⅝″
Depth	28⅛″
Weight	475 lbs.

2J4905-B1

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Super Turnstile Antenna For Television

Types TF-3A, TF-3B, TF-6A and TF-6B

Features

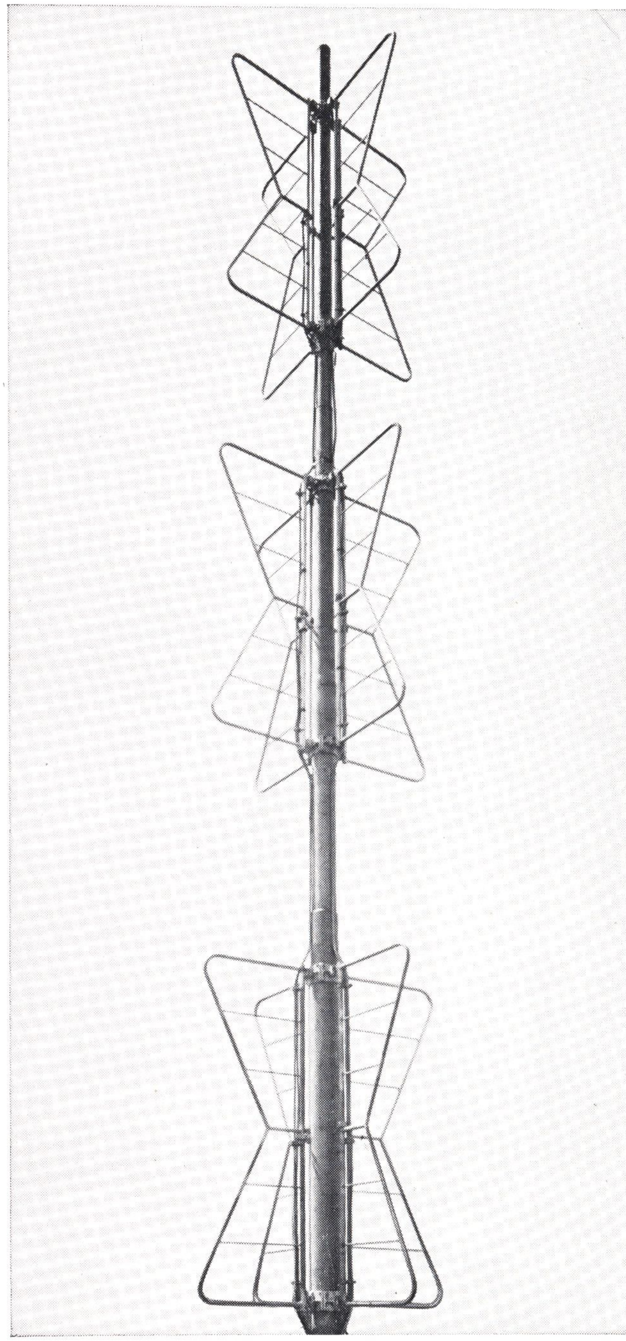
- Extremely broad frequency characteristic
- High gain for given height.
- Permits diplexing of visual and aural signals into same antenna.
- No critical field adjustments—no coupling networks at tower top.
- Furnished complete with all fittings and hardware.
- Grounded for lightning protection.
- No weight supported by insulators.
- Attractive appearance—adds to appearance of tower structures.

Description

The new RCA Super Turnstile for television broadcasting is a multi-element antenna system radiating horizontally polarized waves with a circular radiation pattern. An increased gain is accomplished by concentrating the radiation in the horizontal direction at the expense of radiation in the vertical direction. This gain increases with the number of sections, or layers, used in the antenna; however, practical considerations establish a maximum limit.

Each section of the antenna consists of four radiators mounted at intervals of ninety degrees around a steel pole. The individual sections are mounted approximately a wavelength apart, center to center. These radiators are attached to the steel pole at both the top and bottom so that the complete structure is grounded for lightning, and no weight is carried by endseals or insulators.

The radiators are fed by means of coaxial transmission lines. Each set of opposing radiators may be considered as comprising a horizontal dipole antenna. The outer conductor of the transmission line is connected to one radiator, and the inner conductor is connected to the opposite radiator. Connection is made at the center of the inner member of each radiator. In the event of icing, therefore, only the central part of each section is subject to impedance change. Ice formations can be prevented, however, by the use of sleet melting resistors, which will be provided, if specified. The sleet melting elements are inserted into the vertical tubing of the radiating elements which are adjacent to the pole. This will prevent ice formation between the radiator and the pole—this being the only place where ice formation will have a detrimental effect.



Three Section Super Turnstile. The center pole is self-supporting and may be mounted on top of a suitable building, mountain or a supporting tower similar to that used for standard band broadcasting antennas.

The individual radiators consist of frameworks of narrow diameter seamless steel tubing with cross members of cold rolled steel rods. This open construction results in an antenna with a rather low value of wind resistance, and the somewhat triangular shape of the radiator forms a structure which is

TELEVISION TECHNICAL TRAINING PROGRAM

SECTION V

TELEVISION TRANSMITTER THEORY

SECTION V

TELEVISION TRANSMITTER THEORY

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TELEVISION TECHNICAL TRAINING PROGRAM

TELEVISION TRANSMITTER THEORY

FCC REGULATIONS- Specifications of Performance:

a. Twelve channels are provided, from 54 to 216 mc.

b. The width of the standard television broadcast channel shall be 6 mc.

c. It shall be standard to locate the visual carrier 4.5 mc lower in frequency than the unmodulated aural carrier.

d. "Vestigial sideband" transmission shall be used with the idealized amplitude characteristic shown in Figure 5.1.

e. It shall be standard that a decrease in initial light intensity cause an increase in radiated power (negative transmission).

f. It shall be standard that the black level be represented by a definite carrier level, independent of the light and shade in the picture; that is, the "d-c component" must be transmitted.

g. It shall be standard to transmit the black level at 75% ± 2.5% of the peak carrier amplitude.

h. It shall be standard to rate the transmitter in terms of its peak power when transmitting the standard television signal. This represents peak of "sync" power. "Carrier power" has no significance when the d-c component is transmitted.

i. Amplitude modulation shall be standard in the visual transmitter, and the radio-frequency amplitude shall be reduced to 15%, or less, of the peak amplitude for maximum white.

FURTHER CRITERIA FOR TRANSMITTER PERFORMANCE have been specified by RMA:

a. The carrier frequency of the visual transmitter shall be held to within ± 0.002%.

b. The peak-to-peak variation of transmitter output within one frame of the video signal due to all causes, including hum, noise, and low-frequency response, measured at both sync peak and pedestal level, shall not exceed 5% of the average overall sync peak signal amplitude. Thus all effects of hum and poor low-frequency response must be 25 db down.

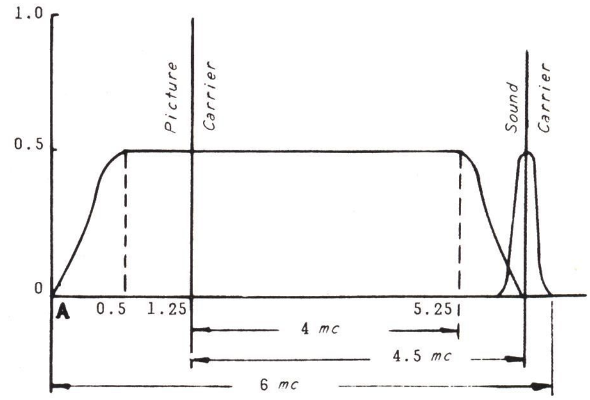

Figure 5-1 - Vestigial Sideband Amplitude Characteristic

c. The RMA recommended that, for normal transmission, the characteristic of transmitter output voltage versus brightness of subject be substantially logarithmic.

These regulations define, in general terms, the performance specifications of the visual transmitter. We see that we must operate in the medium- to semi-high-frequency part of the spectrum, radiating sidebands from dc out to 4.5 mc, using vestigial sideband transmission with amplitude modulation. The minimum depth of modulation must be 15 percent, and black in the picture must represent increased power. The carrier stability is defined, and the total of hum, noise, and low-frequency response on the carrier must be at least 26 db down. The specifications on amplitude linearity, as it concerns the transmitter only, are covered up by the logarithmic character of the camera output, and will be discussed later.

IDEALIZED TRANSMISSION CHARACTERISTIC

THE IDEALIZED TRANSMISSION CHARACTERISTIC of the FCC governs transmitter design in several respects. First of all, this vestigial sideband characteristic lops off part of the lower sideband, and ideally transmits out to 4.5 mc for the upper sideband and 1.25 mc for the lower. This is basically to save channel space, but it is also a receiver problem. In any vestigial or single-sideband transmission and reception system, we deliberately throw away an amount of information, quantitatively in direct relation to the percent of one sideband which is attenuated, since one sideband only yields 50 percent modulation. As long as one sideband is unaltered, the quality and resolution do not suffer. In the receiver, the i-f systems can be built with only half as much bandwidth, and the loss of signal is regained by adding a stage of video without any net increase in receiver cost.

BANDWIDTH

THE BANDWIDTH required to transmit a picture is basically a function of the number of picture elements which must be reproduced, and the speed at which an element must be scanned. In terms of picture constants, bandwidth is given by the relation

$$f_{max.} = \frac{w}{h} \frac{kfn^2}{2}$$

where w/h is the aspect ratio (4/3), k the utilization ratio (0.75), f the frame repetition rate, and n the total number of lines. The expression is for equal vertical and horizontal resolution. Thus for a 525-line, 30-frame picture, $f_{max.}$ equals 4.15 mc. For double-sideband transmission, a total bandwidth of 8.3 mc would be required.

There are several ways of thus squeezing a 525-line picture into a 6-mc channel. The most important are known as the RA, or Receiver Attenuation system, and tha TA, or Transmitter Attenuation system. The RA system is the one authorized by the FCC, and the frequency response through such a system is shown in the accompanying graphs, Figure 5-2. These curves are typical only of a high-level modulated-type of transmitter.

It is important to note the curtailment of high-frequency response in the receiver output, as compared to the response of the transmitter input. Studio equipment (and also the transmitter, to a lesser degree) is intentionally designed for greater response in the high end, to avoid any picture degradation, other than that actually imposed by the basic limitations of channel width. Since the receiver must adhere strictly to channel requirements, its reproduced picture will not contain as much detail as that actually transmitted. This factor should be taken into account when analyzing system performance.

The essence of proper vestigial sideband system operation is the fact, that, in the region of carrier out to 1.25 mc, the transmitter and receiver must have complementary phase and amplitude characteristics, as shown in (d) and (e), Figure 5-2. The transmitted signal has double amplitude response in the low-frequency end, which poses a monitoring problem, since a simple diode will not suffice.

Two other rather important matters arise in connection with sideband energy distribution. The first relates to the points designated as "a" in the FCC idealized characteristic. The regulations state that, at 1.25 mc below the visual carrier and at 4.5 mc above the carrier, the relative field strength shall not exceed 0.0005 to prevent adjacent channel interference. This value representa an attenuation of 60 db with respect to the 0.5-value of normal sideband amplitude. This appears rather severe, particularly at the point 1.25 mc below the carrier. However, Kell, Brown of RCA, and Keister and associates of GE, have made calculations and measurements which show that, for an average picture, the voltage components of sidebands in the vicinity of carrier ±1.25 mc are at least 40 db down. The transmitting equipment, then, must furnish the other 20 db. The RTPB has taken cognizance of this relationship, and has recommended to the FCC that equipment performance be judged on the basis of -20 db being satisfactory.

SIDEBAND ATTENUATION

SIDEBAND ATTENUATION may be obtained by two basic methods, which, for want of better terminology, may be referred to as the GE method and RCA method. The GE method uses low-level modulation followed by a multiplicity of broadband, linear r-f amplifiers, with each stage carefully tuned off-center so that the overall response gives the desired pass-band and attenuation. The RCA system uses high-level modulation, though not necessarily in the last stage, and then inserts a filter system between the PA stage and the antenna. In medium-power transmitters, *i.e.*, around 5-kw peak output, it is technically and economically feasible to build a video system with good frequency characteristic and a voltage output sufficient to modulate the grid of the final stage. If, however, we consider modulating the grid of a 40- or 50-kw output stage, we find that (1) the increased requirements of voltage necessitates water-cooled tubes; (2) water-cooled tubes with good modulator characteristics are not available; (3) overall cost is greater; and (4) we can get about the same power output by operating the 40-kw stage as a class B linear amplifier.

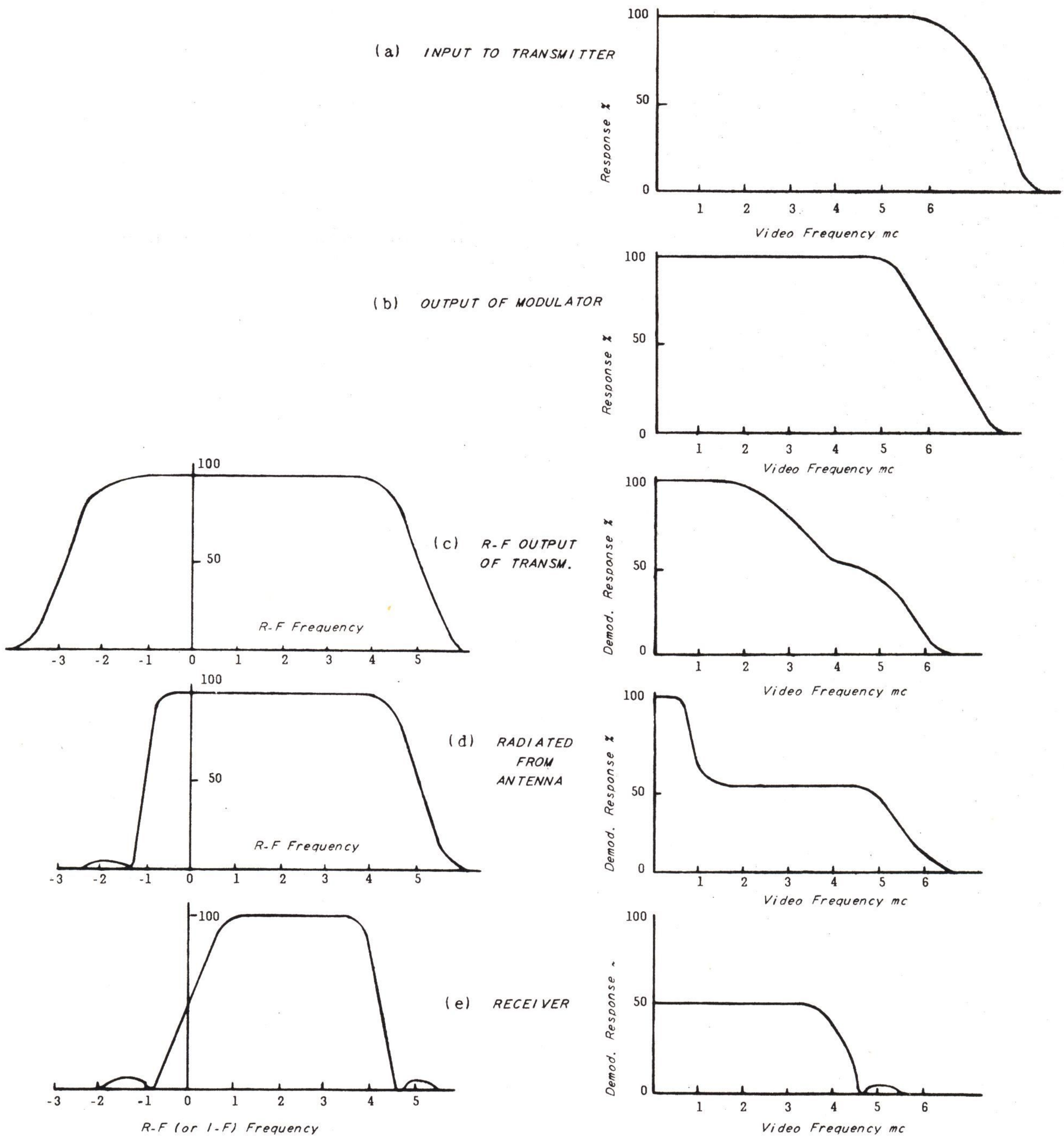

Figure 5-2 - Frequency Response Through a Television Transmitter System

The RCA system, as used in the TT-5A transmitter, modulates the final stage of a medium-power transmitter and the next-to-the-final stage of a high-power transmitter. In either case, there are tuned tank circuits between the points of modulation and the transmission line; and the response characteristic, which of course must be broadband, can be set with respect to the carrier frequency in such a way as to aid in the attenuation at the points "a". This not only provides a safety factor for the vestigial sideband filter, but, what is more pertinent, such adjustment allows the PA to work into a higher impedance, since the pass band is smaller, and hence to be capable of putting out more power.

NEGATIVE TRANSMISSION

NEGATIVE TRANSMISSION means that the transmitter power decreases as the light intensity into the camera increases. In England and pre-war Europe, positive transmission was used, *i.e.*, increased power with increased light. The reasons for standardizing on negative transmission in this country are based on two facts: (1) Noise produces areas of lack of light, or black spots, which are considered to be less bothersome to the eye than bright spots, and (2) a much simpler receiver AVC system can be built if the blacks go in the increased-power direction. Since the blanking pedestal must represent black, the combined pedestal and sync pulse must modulate the transmitter in the "up" direction. Herein lies a disadvantage of negative transmission. To obtain increased output from a PA during the sync pulse interval, its grid must be driven into the positive or grid-current region, and the tendency is to saturate sync; or to reduce the amplitude of the sync pulses with respect to the rest of the signal. This, of course, does not happen with positive modulation; but a certain percentage of saturation of the whites is probably preferable to loss of sync voltage at the receiver. However, precautions can be taken to minimize sync saturation, and these will be discussed later.

There is another important advantage in using negative transmission, which ties in with the FCC specifications stating that the black level shall be transmitted at 75 percent of the peak carrier height. Since the blacks and the sync signals modulate in upward direction, the transmitter must hold peak power only for the duration of the sync pulse. Since the pulses are relatively short, about 6 microseconds for horizontal and 75 microseconds for vertical, they do not contribute appreciably to PA anode dissipation. The voltage and power relations are as shown in Figure 5-3.

The voltage curve shows the relationships of black level to sync tips as specified by the FCC, on the basis of sync tip height equal to unity. If we now re-plot this curve in terms of power, still using the sync tips as unity, it is seen that black level represents $(0.75)^2$, or 0.56, of peak power. Now, the sync pulses contribute additional power in proportion to their total duration and repetition rate. If a complete signal is analyzed, including both horizontal and vertical sync pulses, it is found that their total duration is equal to 0.1 of the repetitive time interval; therefore, the power they contribute is 0.1 (1.00 - 0.56) = 0.044, or a total of 0.56 + 0.044 = 0.604, or 60% of peak of sync power. Anode dissipation is proportional to power output (assuming constant plate efficiency). Therefore, for a given tube complement with a given anode dissipation, the output can be increased 40%. If positive modulation were used, the output stage would have to be capable of handling continuous power equal to the peak power whenever a white picture came along.

In addition to the stipulation that the black level be 75% of the peak r-f amplitude, it is also specified that this black level represents a definite power level independent of changes in the picture itself. This means that the peaks of sync also represent a certain power level, since the ratio between black level and sync peaks is fixed. The picture transmitter could thus be rated (in power output) in terms

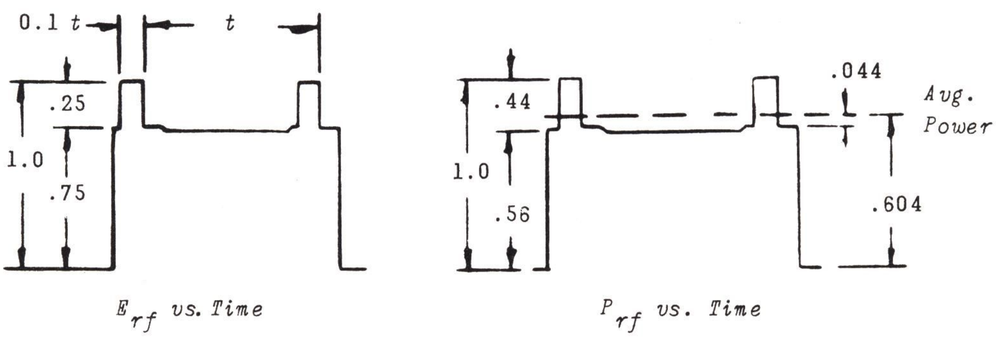

Figure 5-3 - Voltage and Power Relations for Negative Transmission of either black level or sync peaks. The sync peak level was chosen because, at the time the old NTSC considered this matter, there was considerable discussion on what percentage of the signal should be devoted to synchronizing, and hence what percentage of the signal would be black level. So to avoid any possible confusion in the future, in case the percent of sync was changed, the peak of sync level was chosen.

To appreciate the significance of maintaining the sync peak at a certain fixed power or voltage level, it is necessary to look briefly at the d-c component of the signal; how it is obtained, and how it is handled. The discussion must start with the studio camera, and end with the receiver kinescope. It is in the output of the camera tube itself that the composition of the picture signal must be recognized and handled properly. In any picture scene which is to be transferred to electrical wave form, the signal can be said to contain two generalized components: One, the detailed information, which is the a-c component; and the other, the background, or d-c component. The background is simply the average illumination of the whole scene, taken over the interval of one complete picture frame. The image orthicon and the Farnsworth dissector tube are direct-coupled devices and automatically supply both components. The iconoscope, depending as it does, on a multiplicity of sensitized, capacity-coupled cells, puts out only the a-c component, referred to some arbitrary axis. The scene must therefore be viewed with an auxiliary light-sensitive device such as a photocell, whose output, suitably amplified, controls the bias of an appropriate tube in the unit in which the camera signal is combined with the sync signals (see Figure 5-4).

Thus, it is apparent that true d-c insertion is accomplished at the camera, and that fundamentally this consists of properly locating the camera a-c output voltage wave form with respect to the blanking pedestal or black level.

To preserve the background component, each amplifier between the camera and the kinescope could be d-c coupled. However, it is neither desirable nor necessary to go to these extremes. When a video signal passes through a capacity-coupled amplifier stage, the signal orients itself around a reference axis which is the average of the entire wave form. Thus, in the output of such a stage, black is no longer black in the sense that it represents a given voltage level, since that level will vary as the symmetry of the wave form varies. However, the relationship between the a-c wave form and the blanking pedestal has not been lost. In fact, the only thing that is lacking is the establishment of the black level to represent a given voltage or power output, as the case may be. Through relatively simple circuits, the black level may be re-established at any desired point in the television system. Not many years ago, before the value of establishing the black level in the transmitter was recognized, re-insertion was not applied until the signal reached the grid of the kinescope. At this point, a simple diode was connected across the grid resistor, and the desired reproduction was obtained.

LIMITING WAVE FORMS

Before pointing out the advantages of establishing the black level in the transmitter, let us look briefly at the *limiting wave forms* encountered in video signals, as illustrated in Figure 5-5.

The all-white and the all-black (with a white line) pictures represent the extreme cases, and typify the nature of the departure from symmetry which we nearly always encounter in video signals. The significance of this phenomenon

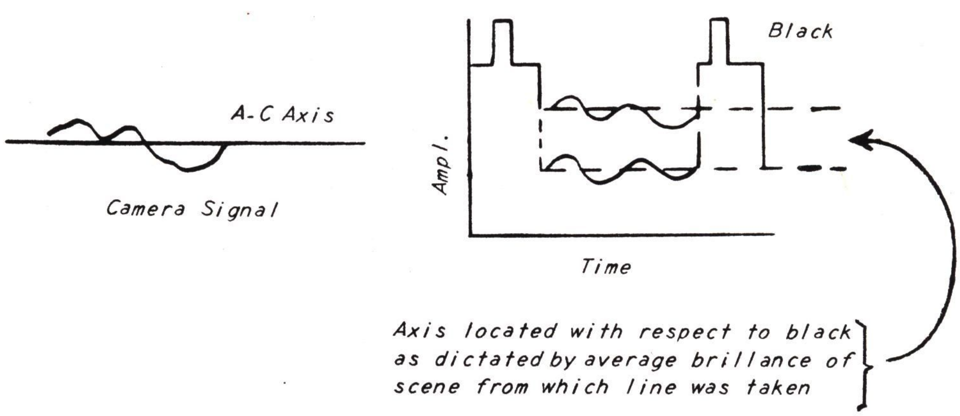

Figure 5-4 - Picture Signal Showing D-C Component

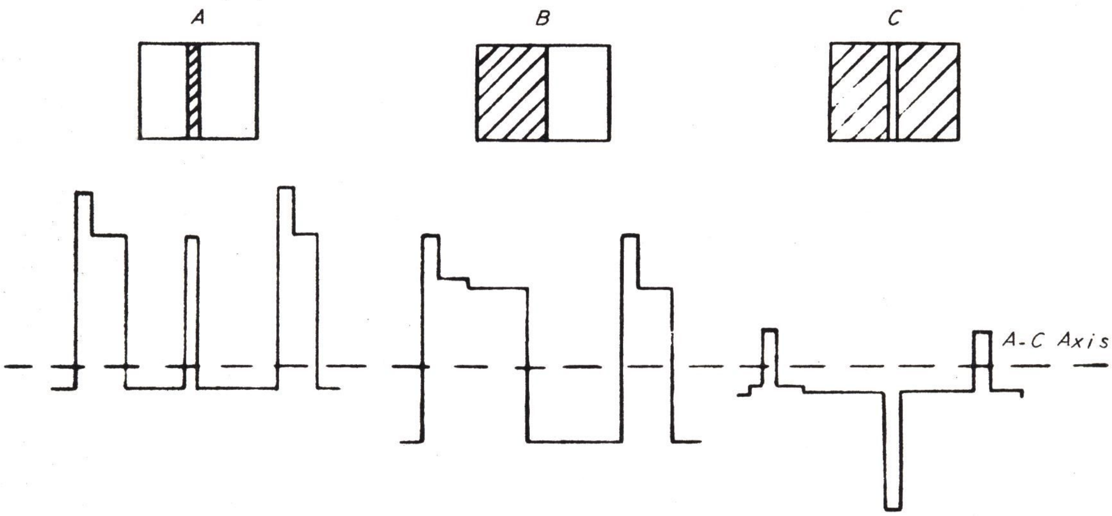

Figure 5-5 - Limiting Wave Forms in Video Signal

is seen when we think of these unsymmetrical wave forms in terms of voltage swings on the tube characteristic. The important fact, for transmitter design, is that a given tube will handle appreciably greater output with d-c re-insertion, although the actual voltage gain remains the same. Kell has shown, after analyzing the areas above and below the axis for the two extreme wave forms, that there is a ratio of 1.5 to 1 for the two cases.

D-C re-insertion allows 50 percent more intelligence to be transmitted in the sidebands, without increasing the carrier power, and hence without increasing the interference range of the transmitter. From the foregoing, it is seen that it is particularly advantageous to re-insert the d-c component in high-level stages, both video and r-f, where voltage-swing limitations are encountered. In present designs, this practice is followed, in that the d-c component is re-inserted in the grid of the last video or modulator stage, and preserved on the grid of the modulated stage by d-c coupling.

MODULATION

The last point in our standard specifications for television transmitter concerns modulation. Amplitude modulation for the video signal is specified and *grid modulation* appears to be the preferred method for the very-broad-band systems, and for systems requiring transmission of the d-c component. A similar analysis for narrow-band sound transmission will probably yield the opposite answer, and one of the deciding factors, in this comparison, would be distortion. High-output grid-modulated stages yield such high distortion as to be intolerable for high-fidelity transmission. In order to work on the truly linear portion of an r-f amplifier characteristic, it is necessary to stay almost entirely in the negative grid region, and thus a very considerable amount of power must be sacrificed. In television signal transmission, much greater distortion can be tolerated, and as a matter of fact the right kind of distortion is invited.

Referring to Figure 5-6, all camera tubes

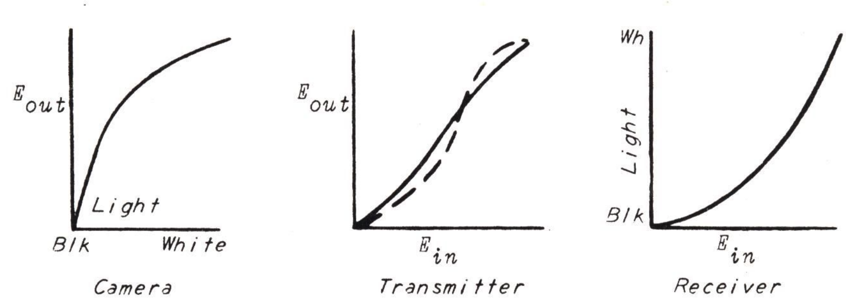

Figure 5-6 - Linearity Characteristics of TV System Elements have an amplitude-linearity characteristic which flattens off in the white region and is expanded in the black. Camera circuits could be designed to correct this, but it so happens that the receiver kinescope has an opposite, and nearly complementary, characteristic. Thus, at the receiver the response in the black region is contracted. Because, with negative transmission, noise, and interference bursts are in the black direction, this kinescope characteristic is very desirable, since it tends to saturate off noise peaks. It is very much akin to pre-emphasis of high's in a sound transmitter, so that the receiver can de-emphasize and attenuate noise. The RIPB recognized this feature, and recommended that the amplitude linearity of the transmitted television signal be "logarithmic", and the receiver "exponential". Furthermore, the transmitter and receiver characteristics can depart considerably from being complementary without affecting anything except the relative shades of black and white in the picture, the optimum value of which changes from one scene to another. It is apparent then, that the characteristic of the transmitter proper can be allowed to vary considerably from linearity, particularly in the white region, without appreciably changing the desired systems characteristic. It is important, however, to watch closely the linearity in the black region, since the sync signal must be held to +0, -2 percent of specified amplitude.

TELEVISION TECHNICAL TRAINING PROGRAM

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SECTION VI

TELEVISION TRANSMITTER EQUIPMENT

RCA TELEVISION TRANSMITTER, TT-5A
RCA TELEVISION TRANSMITTER, TT-500A
RCA TELEVISION TRANSMITTER, TT-500B

SECTION VI

TELEVISION TRANSMITTER EQUIPMENT

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TELEVISION TECHNICAL TRAINING PROGRAM

THE NEW RCA TELEVISION TRANSMITTER TT-5A

INTRODUCTION

The TT-5A Television Transmitter is designed for use in all television stations where an economical, compact, high-fidelity picture and sound transmitter is required. It covers all 12 television channels assigned by the FCC for metropolitan use, and assures a signal of 5-kw peak power on each channel.

Unified styling in cabinet design gives the pleasing appearance of single-unit construction, and yet the 8 individual cabinets of the TT-5A, when installed, can be arranged to suit nearly any station layout.

Operating from video picture and sound inputs of standard levels, the TT-5A delivers an r-f signal in accordance with FCC and RMA standards. Compliance with these standards is brought about by positive means which cannot be affected by transmitter tuning or any non-linearity in the power amplifier.

All r-f exciter and driver stages are straightforward *narrow-band* amplifiers which can be tuned quickly and accurately by meter indications. High-level modulation is applied to the grid of the picture power amplifier, and provision is made for maintaining the d-c component and for maintaining linearity in grid-circuit loading.

The picture power amplifier, the only broad-band r-f stage in the transmitter, employs the new, efficient RCA-8D21 dual tetrode. This tube is specifically designed as a high-frequency, grid-modulated power tube for wide-band operation, and incorporates advanced principles of screening, cooling, and electron optics. The screen-grid construction and internal neutralization of the residual grid-plate capacity assure unusually high stability, while the efficiency of the tube provides operating economy. Moreover, a gain of 10 in the tube permits use of a small r-f driver and modulator, effecting further economy.

A master monitor, in the center of the console, can be quickly switched by push buttons to the input of the transmitter, the output of the modulator, or the output of the sideband

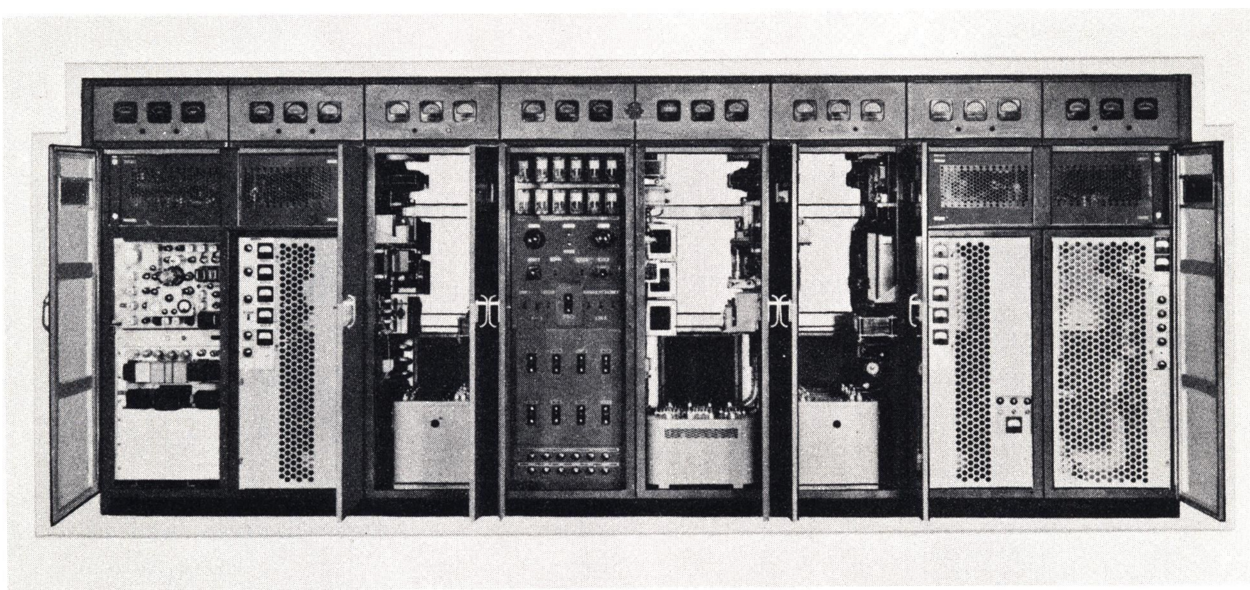


Figure 6-1 - TT-5A Television Transmitter, with front doors open to show accessibility. Frames 1 and 2 house the sound transmitter; frame 3, the sound-transmitter power supplies. Frame 4 is a centralized control panel for both sound and picture transmitters. Frames 5 and 6 contain the picture power supplies, while frames 7 and 8 house the picture transmitter. Each frame also has a full-length rear door, to give to each compartment maximum accessibility.

filter. Both the picture and its wave form, as well as sound, can be monitored in this way.

Another new feature in the TT-5A is the "reflectometer", a unique device in the transmission line, which indicates the standing-wave ratio on the line. The reflectometer also "looks" toward the transmitter, indicating relative power output as required by FCC. The relative power output and standing-wave ratio indications appear at both the transmitter and the console.

The control circuits of the TT-5A television transmitter are arranged for maximum convenience. The picture and sound transmitters can be operated independently. For example, emergency maintenance or servicing work can be done on either transmitter while the other is on the air, even to changing power amplifier tubes. All critical power supplies are electronically regulated, enabling stable, high-quality performance under all conditions of load or line voltage fluctuation.

STATION LAYOUT

Unit construction permits flexible station layout and advantageous use of floor space. For the straight-line arrangement, the overall width is 208 inches. Also possible are several U-arrangements, providing a minimum width of 150 inches.

Transmitting equipment also includes console, vestigial sideband filter, dummy load, water-cooling equipment, and racks for monitoring and pre-amplifier equipment.

Figure 6-8 is a plan view of a typical TT-5A installation showing both low-frequency (channel 2 to 6) and high-frequency (channel 7 to 13) versions.

CIRCUIT DESCRIPTION

GENERAL - The TT-5A transmitter is designed around the RCA-8D21 dual tetrode. For the first time, a power tube has been designed specifically for use as a broad-band, highly stable, high-gain television transmitter tube capable of being easily grid-modulated and operating at frequencies well above the highest television channel. It is a good broad-band tube because the "figure of merit", the ratio of filament emission current to output capacity (3.0 $\mu\mu f$ anode-to-anode), is unusually high. This filament emission is obtained at very low heating power (550 watts) by the use of a new filament ribbon construction of "thoria on tungsten on tantalum". Low tube capacities are achieved by utilizing advanced principles of water cooling which require slightly higher pressures (60 pounds) but very low rate of flow. A total of only 1.5 gpm is required for each 8D21 tube. As an example, each anode will dissipate approximately 370 watts per square centimeter, as compared to 30 watts for older types of tubes. This type of cooling allows *all* tube elements to be built smaller in about the same proportion; hence all interelectrode capacities are very materially reduced. Thus, operation at frequencies as high as 300 mc is readily achieved with open-type tank circuits and without having to "bury" the tube in a cumbersome, inaccessible concentric-line structure.

The stability required in the modulated amplifier stage of a television transmitter is many times greater than that required in any other type of service. The stage must not merely be kept below the point of oscillation; rather, the feedback must be kept many fold below this value to avoid severe distortion of the band-pass characteristic. The push-pull, tetrode construction of the 8D21 makes possible unusually low grid-plate capacities and substantially zero inductances in cathode and screen circuits, and thus eliminates the major causes of input-output feedback.

A good television modulated amplifier tube should be capable of high power gain, and should have grid-current characteristics which will permit video modulation of either the excitation or grid bias with reasonably low value of video voltage and a substantially linear amplitude characteristic. This is achieved, in the 8D21 dual tetrode, by applying the principles of electron optics, or electron beaming. The construction of the filament and filament block, and the location and disposition of control-grid and screen-grid wires are such that a minimum number of electrons are intercepted by the grid. Hence, "grid absorption" is low, power gain is high, linearity is good in the sync region, and the tube may be modulated by a very reasonable amount of video voltage.

PICTURE CHANNEL - Figure 6-9 is the simplified schematic diagram of the picture portions of the TT-5A transmitter.

The frequency of the picture carrier is established by a temperature-controlled crystal in the oscillator stage. An RCA-1614 tube is employed in this stage and its plate circuit is tuned to twice the crystal frequency.

Figure 6-2 shows the complete r-f driver system, as used on channels 2 to 6. Link-coupled to the oscillator is an RCA-4E27 doubler with tuned input and output circuits. This doubler feeds an RCA-4E27 tripler which is, in turn,

Figure 6-2 - Low-power Stages of Picture Transmitter mounted in frame 7, just below the grid-circuit of the picture PA. Note the crystal oscillator unit in box at lower right. This contains three crystals, one of which is not visible in this view. These consist of the regular video-channel crystal, a spare crystal of the same frequency, and a "tune-up" crystal of mid-band frequency.

inductively coupled to the tuned grids of two RCA-4-125/4D21 tubes in push-pull. For the frequency range of 54-88 megacycles, the push-pull stage drives the RCA-3D21 power amplifier tube. For the 174-216 megacycle range, additional r-f stages are inserted to provide adequate drive for the power amplifier. The additional r-f unit utilizes two RCA-4-125/4D21 tubes as a push-pull tripler, driving a pair of RCA-4X500A tubes, also in push-pull. Sufficient shielding within the RCA-8D21 power amplifier tube and between the input and output circuits of the amplifier stage precludes the need for neutralization. (The grid tank circuit tunes to one-quarter wavelength on channels 2-6, and to three-quarters wavelength on channels 7-13.) Video modulation is applied to the grids of the 8D21 tube.

A "damping" circuit, in the grid circuit of the power amplifier, absorbs a constant amount of r-f power from the driver tubes. This tends to minimize (or "damp out") changes in loading on the driver during modulation. Appreciable PA grid current flows at the peak of the synchronizing pulses, as compared to the transmission of white picture elements when no grid current flows. Thus, the r-f driving voltage is held nearly constant over the modulating range, thereby improving the modulation linearity in the high-output region.

Power is coupled from the power amplifier plate tank to the series-tuned output tank, from where it is fed to the transmission line, as shown in Figure 6-3. The plate tank and the output tank are slightly over-coupled and tuned for response over a broad band. A Balun (BALanced to UNbalanced) unit matches the push-pull output circuit to the single-ended transmission line. Controls are brought out to the front panel to permit adjustment of the coupling and tuning of the plate and output tanks. Similarly, all tuning controls for the exciter, multiplier and driver stages are brought to the front of interlocked screen doors behind the front doors of the transmitter.

Coupled to the transmission line inside the transmitter cabinet are two "reflectometers" for measuring both the standing-wave ratio and the relative power output of the transmitter. These devices also protect the transmission

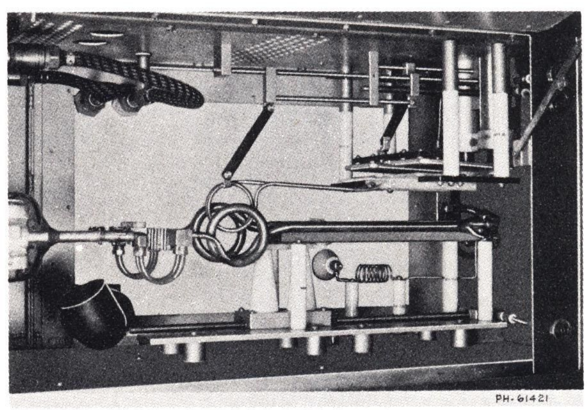


Figure 6-3 - Picture Power Amplifier, close-up view of the plate circuit. (The sound PA is identical, but reversed left-to-right.) Tuning is accomplished by flexible-shaft couplings to calibrated controls at the front. These controls are located behind the front doors, which on these frames are not interlocked.

line from injury by high-voltage surges which might be caused by mistermination of the line, lightning, etc. The reflectometer is basically a peak-reading vacuum-tube voltmeter. Its pickup coil is so designed that, when coupled to a properly terminated line, where no standing waves exist, the voltage pickup due to inductive coupling equals that due to capacitive coupling; and a meter in the output circuit of the diode rectifier reads a value proportional to the sum of these voltages. If, however, either the polarity of the voltage on the transmission line is changed or the connections of the pickup coil are reversed, the output meter will read zero. Since the waves travelling from the transmitter to the antenna are of opposite polarity to those returning from the antenna to the transmitter, the outgoing as well as the incoming waves can be measured. Two reflectometers are used, one with the pickup coil oriented to indicate the incident wave, and the other the reflected wave.

After the incident-wave reflectometer has been calibrated with a dummy load, indications of transmitter peak-power output are directly obtainable. The other reflectometer head -- the one responsive to the reflected wave -- also controls the bias voltage of an RCA-2050 tube, which fires and actuates overload relays when the voltage travelling toward the transmitter exceeds a predetermined value.

VIDEO MODULATOR - The picture amplifier and modulator unit (see Figure 6-4) includes two video amplifier stages, the modulator stage, sync expander, sync separator, sync amplifier, and a d-c insertion diode. Three RCA-6AG7 tubes in parallel comprise the first video stage. Input level can be controlled either at the transmitter or from the console. Control of the gain from the console is achieved by a reversible motor which drives the gain potentiometer.

From the first amplifier, video signals pass through a high-frequency compensating network to the second video amplifier, consisting of two RCA-807 tubes connected in parallel. To compensate for the loss in sync-pulse amplitude in the succeeding modulator and power amplifier stages, an RCA-6AG7 tube is connected in parallel with these 807's. Since the 6AG7 tube has high transconductance (and sharp cut-off), it is used to expand the synchronizing pulse. This is done by using the plate current of the tube to increase the combined plate currents through the amplifier load during the pulse interval. The 6AG7 tube can increase the pulse amplitude by approximately 30 percent without increasing the amplitude of the picture signal. Its plate current is controlled by a potentiometer in the screen circuits.

Six RCA-4E27 tubes in parallel modulate the

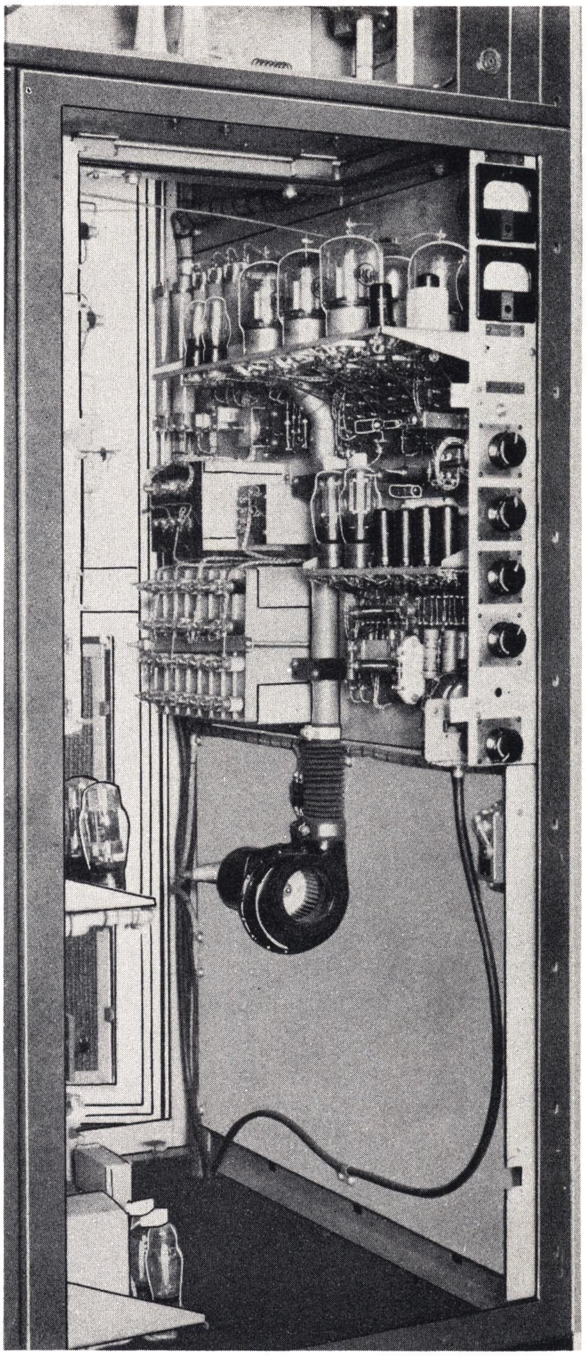


Figure 6-4 - Video Modulator Unit. Compact and Relatively simple, this unit includes three straightforward video stages (the last of which develops all the video power needed fully to modulate the RCA-8D21 tube in the picture PA), plus the sync separator and expander circuits required in all video transmitters. By this simple, fool-proof unit, high-level modulation can be used, eliminating the chain of Class B linear stages which are necessary in "low-level" transmitters.

grids of the power amplifier. The modulator plate load is a constant-resistance network having four high-frequency sections and three low-frequency sections. This network maintains a constant impedance of 500 ohms over the entire video band. The section which tunes to the lowest frequency in the band utilizes the internal resistance of the modulator power supply as a portion of the plate load, permitting excellent frequency response down to and including dc.

A "clamp"-type d-c restorer circuit is used in the modulator stage. This circuit, which actually employs a sync separator (RCA-6J5), a sync amplifier-inverter (RCA-6AC7), and a biasing and restorer tube (RCA-6H6), partially disables the modulator tubes during the last part of the horizontal blanking signal immediately after the sync interval. This clamping action reduces to negligible amplitude such spurious low-frequency signals as microphonics, power-supply surges, and 60-cycle hum introduced in preceding stages.

The horizontal sync separator is transformer-coupled to the sync amplifier and phase inverter. The transformer is tuned by associated tube and stray capacities so that one-half cycle at its resonant frequency has a duration of approximately two microseconds. Highly damped by core losses, and to some extent by circuit losses, the transformer dissipates its stored energy in the form of a pulse which is then amplified and inverted by the 6AC7 tube. Phase inversion is necessary to make the 6H6 clamp the modulator on the rear portion of the horizontal blanking signal. Thus, modulator bias is automatically corrected to the same predetermined value for each blanking pulse, and in effect, the d-c component restored.

For test purposes, it is desirable that the transmitter be capable of being modulated with a signal which is symmetrical above and below the axis, such as a sine wave, video sweep, or square wave. This type of signal is unusual for a television transmitter and requires special adjustments which differ from those for a standard composite television wave form. This adjustment is termed "mid-characteristic" operation, and the changeover from normal "d-c restorer" operation is accomplished by an "AC-DC" switch. With this switch in the "AC" position, the grids of the second video amplifier, the sync amplifier, and the modulator stage tubes are returned to a manually adjusted bias source. In addition, the clamping circuit tubes are biased to cut-off.

An RCA-6AG7, coupled through a resistance attenuator to the output of the picture modulator, functions as a phase inverter, producing video signals of negative polarity for the monitor in the console.

POWER SUPPLIES (for picture portion) - Plate and screen voltages for the picture r-f portion of the transmitter are furnished by power supplies located in frames 5, 6, and 7 of the transmitter. By equally dividing the power supply components between these three frames, overcrowding was avoided, resulting in easiest accessibility to all components of the transmitter.

Frame 6 houses, in addition to the 5000-volt supply for the plates of the power amplifier, a regulated 800-volt d-c supply which furnishes screen voltage to the power amplifier, and a 1500-volt supply for the plates and screens of the oscillator stage, the frequency multipliers, and drivers. The driver plate transformer is in frame 5, and the voltage dividers for this supply are in frame 7. The 5000-volt and the 1500-volt power supplies both use 3-phase, full-wave rectifier circuits, the 5000-volt supply employing six RCA-8008 rectifiers and the 1500-volt supply utilizing three RCA-8008 rectifiers. The electronically regulated 800-volt supply uses two RCA-816 tubes in a single-phase, full-wave rectifier circuit. A knife switch is provided for changing the primary circuit of the high-voltage transformer from a delta to a wye connection for tune-up operation.

Modulator plate voltage is obtained from a 1000-volt supply using six RCA-8008 rectifiers. From voltage dividers in this supply, 600-volt dc is fed through an electronic voltage regulator and applied to the modulator screens and to the plate and screens of the video amplifiers. A 300-volt d-c supply furnishes bias voltages for both the video and r-f stages of the transmitter.

An electronically regulated, single-phase, full-wave rectifier supplying 1100 volts dc provides the negative reference voltage which opposes the variable (with d-c component) positive voltage at the modulator plates. This bias supply is connected between the plates of the modulators and the grids of the power amplifier through the high-frequency portion of the constant-resistance network.

Of the various modulation methods, RCA has chosen high-level grid modulation as being the most practical, efficient, and economical, particularly for powers of the order of 5 kilowatts. It affords much greater simplicity in driver-circuit design and adjustment than do low-level modulation methods. Moreover, slight maladjustment of the driver stages feeding a modulated power amplifier has no detrimental effect on picture quality, as long as correct drive to the PA is maintained.

It may be of interest to discuss briefly the underlying principles involved. It is manifestly true that the ultimate objective is to feed to the radiating system an r-f signal modulated by picture sidebands of an amplitude compatible with the rated output power. This sideband energy must be obtained by amplification of the low-level output of the line amplifier. This amplification can be accomplished either by broad-band r-f amplifiers or broad-band video amplifiers. *The same picture energy amplification must be accomplished in either case.* It is RCA's opinion that the picture signal should be built up at video frequencies to as high a value as possible with simple, straight-forward tubes and circuits, and without utilizing water-cooled tubes for the modulator stage. Video is then combined on the carrier at this level. In the TT-5A, this point occurs at the grid of the final stage. For higher powers, a single linear amplifier would be used. Thus, video band-pass characteristics are accomplished in circuits with fixed constants, requiring no adjustments, contrary to the low-level system where the band-pass is entirely a matter of tank circuit tuning.

The FCC regulations state that each station shall keep on hand a stated percentage of spare tubes for each type employed in the transmitter. In some cases, this might represent a large stock of spares, occupying extensive storage space in the station. In designing the TT-5A, an attempt has been made to reduce the number of different tubes required. As a result, even though both the sound and picture channels, with their power supplies, employ 75 tubes, there are only 15 different types. This, we believe, is a worthwhile reduction.

SOUND CHANNEL - The tube complement and circuits of the sound driver and power amplifier are identical to those of the picture driver and power amplifier, and are shown on the schematic of Figure 6-9. Of course, the carrier frequency for the sound channel is higher by 4-1/2 mc, and since a "direct-fm" exciter is used, the carrier frequency is not generated by a crystal oscillator, and the power amplifier is not modulated directly as is the case in the picture channel. But the important advantages of crystal control are also obtained in the sound channel by the use of that well-known f-m exciter used in RCA's dependable "BTF" series of f-m broadcast transmitters. The circuit employed retains the advantage of simplicity and fewer tubes, while at the same time it provides good fidelity and the frequency stability of crystal control.

POWER SUPPLIES (for sound portion) - The f-m exciter unit obtains its operating voltages from a regulated power supply using three RCA-5U4G rectifiers in a full-wave single-phase circuit. A selenium bridge-type rectifier supplies 19 volts dc to operate the filaments of the two reactance tubes, the modulated oscillator, and the first frequency multiplier tube.

A 1500-volt d-c supply, identical to the picture supply, furnishes plate and screen voltage to the r-f driver chain. The screen-grid voltage of the power amplifier tube is taken from a voltage divider in the output of the supply. The rectifier and filter of this supply are in frame 3, the power transformer in frame 1, and the output voltage divider in frame 2.

The power amplifier plate voltage is furnished by a 5000-volt supply mounted in frame 3. This supply is identical to that used for the picture power amplifier. Operation on either high or low power is provided by a switch which changes the connections of the plate transformer from a delta to a wye circuit.

The normal sound input to the transmitter is pre-emphasized according to the standard 75-microsecond pre-emphasis curve. For listening purposes, a 75-microsecond de-emphasis network is included in the console behind the master monitor control panel. When S1112 is in the IN position, the de-emphasis network functions for the signal to the sound monitor amplifier when the transmitter input push button is depressed. When S1112 is in the OUT position, the transmitter input signal appears at the sound monitor amplifier without de-emphasis. Since the de-emphasis network is a dissipative network, the level at the sound-monitor gain control will increase about 20 db, when the switch is changed from IN to OUT. The VU meter reading of the input level is not affected by the de-emphasis network or by S1112.

R-F LOAD AND WATTMETER

The R-F Load and Wattmeter is designed to terminate the output of either the visual or aural transmitter and to allow measurement of the power output of either transmitter.

The MI-19024-A R-F Load and Wattmeter is used with the TT-5A transmitter. This load consists of a vertical cylindrical tube containing the terminating resistor which is immersed in a coolant liquid. Tap water is connected to a heat exchanger coil within the tube, to carry away the heat developed. An internal interlock shuts down the transmitter to protect the load if the water supply fails. A rectifying crystal is connected to a probe on the resistor and indicates r-f power on a d-c milliammeter which is calibrated directly in r-f watts.

The MI-19024-B R-F Load and Wattmeter is used with the TT-500A transmitter described in a later paragraph. This load also contains a resistor which terminates the transmission line, but the unit is air-cooled.

Each unit correctly terminates a 51-1/2-ohm line, and has an input consisting of a section of solid-dielectric flexible cable with suitable fittings for ease of connection to the transmission line from the transmitter.

CONSOLE

The RCA TT-5A console is constructed as an attractively styled control center, where the operator has complete finger-tip control over both the operating and monitoring functions of the transmitter. Note from Figure 6-5 that, provided in the console, are the essential starting and stopping switches, gain controls, indicator lamps, and output meters for transmitter operation, plus complete monitoring facilities for control of both picture and sound signals. Spare push button switches provide for the use of remote picture and sound monitors.

Manual as well as automatic sequence starting is provided. While under automatic operation, repeated overloads produce a three-shot recycling sequence which automatically returns the transmitter to the air up to three times. If such overloads persist, the transmitter is automatically shut down. A special hold-in circuit instantly returns the transmitter to the air after momentary line failures, thus avoiding the normal 30-second delay required for the plate time-delay relay to close.

Monitoring of the sound channel is provided by a VU-meter and speaker circuit. The desired sound level can be maintained at will, and relative indications of r-f power output from the sound transmitter are given by an output meter also located in the console. The monitoring speaker as well as the VU-meter can be switched by push buttons to either the input or the output of the audio channel. Two spare push buttons for switching to either of two input lines, and another spare push button for both the meter and the speaker, are provided for remote monitors or other optional use.

Just as the console provides adequate means for control over the sound signal, it offers comparable facilities for the control of the picture signal. Picture gain can be controlled manually, and power output indications are likewise obtainable on a panel meter in the console. Moreover, facilities for observation of the picture and for analysis of its wave forms are provided in a compact, easy-to-operate master monitor built into the center of the console.

The master monitor is identical to RCA's studio monitor and contains a 10-inch kinescope, 5-inch CRO tube, video amplifiers, a sync separator and sweep circuits. The 10-inch tube serves for observation of the picture, and the

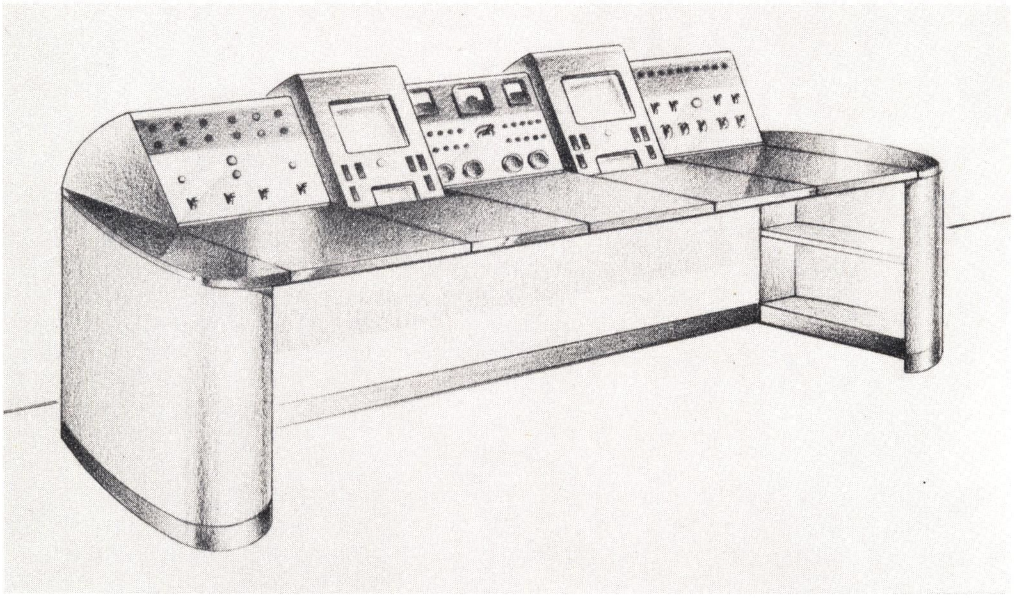


Figure 6-5 - TT-5A Television Transmitter Console

5-inch CRO tube reproduces the picture wave form. For measuring purposes, a calibration circuit establishes a definite voltage level on the oscilloscope screen. The CRO is synchronized (by the separator circuits of the kinescope) at half the sweep frequency of the kinescope. Therefore, two cycles of either horizontal or vertical sync pulses (as selected) appear on the CRO tube screen. The monitor can be operated with composite picture and sync input, or driven by separate picture and sync voltages. The grid circuit of the CRO tube in the monitor is accessible to apply pulse voltages for measurement. Depth of modulation can also be measured. All circuits are easily accessible for servicing.

In use, the few operating controls of the master monitor require only a minimum of adjustment. Upon starting, adjustment of the "hold", focus, and brightness controls is of course required, but thereafter only slight readjustment of the brightness and focus controls may become necessary as tubes age or room lighting conditions change. Aluminum backing on the screen of the kinescope produces a very brilliant picture.

PROGRAM-SWITCHING CONSOLE

For those stations which require facilities for switching program sources at the transmitter site, the "Program-Switching Transmitter Console" is available. This system facilitates rapid switching between two to five television program sources at the Transmitter Console position. Individual presettable gain controls are provided for each picture and each sound source. The several sources of picture and sound may be individually previewed and measured; and their levels may be adjusted at any time, either before switching, or while the program is on the air.

The change from one program source to another is accomplished by mechanically interlocked push-switches. Separate rows of buttons are provided for picture and sound to attain greater flexibility than would result from simultaneous switching by a single button. If simultaneous switching is desired, it is only necessary to press sound and picture buttons at the same time. Two groups of buttons are provided, the left group for program switching and the right group for preview monitoring. These buttons are in two horizontal rows, with corresponding picture and sound buttons one above the other and close enough together to be pressed with two fingers of one hand. Five identical sound and five identical picture channels are provided, so that transfer between program sources can be made instantly at any time. The five channels may be utilized for any combination of program sources, which may include locally generated picture signals such as from slides, film, a monoscope camera, etc., with sound signals obtained from microphone turntables, film, or other source, as well as signals from remote points.

Tally lights are provided on the console adjacent to the push buttons to indicate the circuits in use. Terminals are provided for connecting external indicator lights where needed in announce booths, control rooms, and studios. Also relays can be connected to silence loudspeakers used for cueing in announce booths.

COMBINATION CONSOLE

It is not uncommon to find station layouts in which TV, AM, and FM transmitters are located at one site. In many of these it is highly desirable to combine the transmitter console facilities. To fill this need, RCA has available standard desk sections, 90° desk sections, main turrets, and wing turrets, which may be assembled in any manner desired to form a complete and flexible transmitter console for any number or kind of transmitters. A combination console set-up which is capable of handling a TV, an FM, and an AM transmitter is shown in Figure 6-6. Note that all RCA turret panels, whether AM, FM, or TV, will fit the standardized turret housing. In addition, blank panels are available for specialized customer-built control assemblies. Desks without turrets may be used for a log typewriter.

OTHER FACILITIES SIMPLIFYING TRANSMITTER OPERATION

A full complement of meters and indicator lamps mounted along the top front panel of the transmitter permit quick observation of the performance of the various circuits. Separate panel meters are provided for the grid and cathode circuits of the driver stages and for the grid, screen, and plate circuit of each power amplifier. The meters can be easily read, since the scales and pointers are finished in highly contrasting white on black background.

Switches for separate control of the sound and picture transmitters are mounted on a control panel behind a non-interlocked door. Tuning controls for the sound and picture driver circuits are brought out to the front of interlocked screen doors, behind non-interlocked front doors of the respective cabinets.

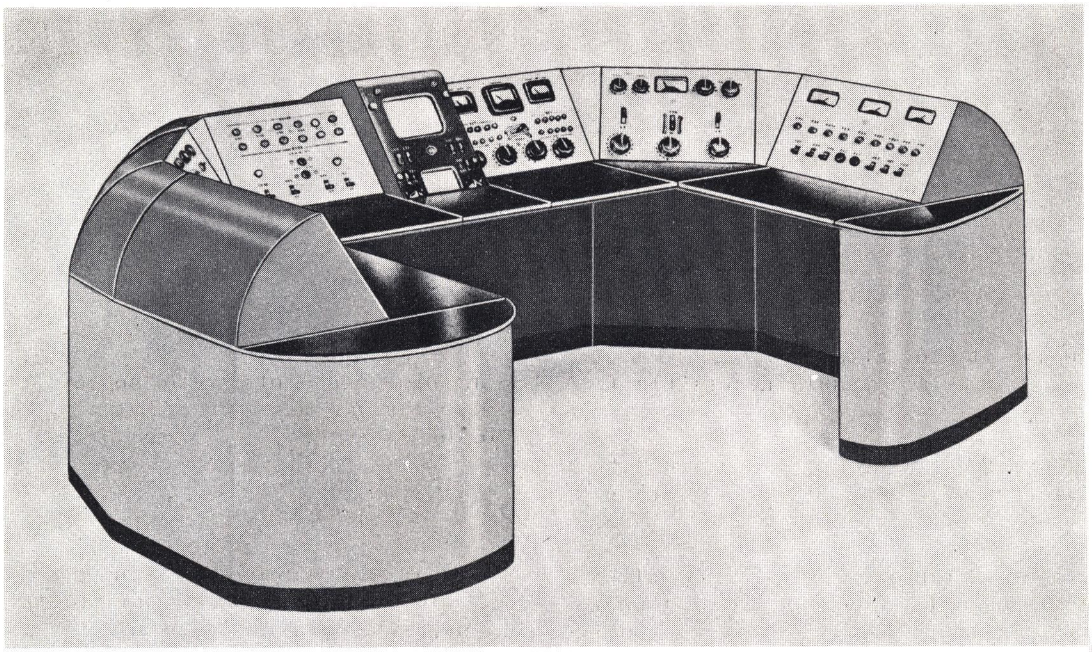


Figure 6-6 - Combination Consoles may be set up for control of any number of different types of transmitters. The above console set-up will handle a TV, an FM, and an AM transmitter.

The circuit arrangement and mechanical layout of the transmitter permits maximum accessibility. "Walk-in" type construction is employed throughout, as shown in Figure 6-1. Sub-assemblies are mounted to side panels providing easy access through both front and rear interlocked doors. Where possible, components are surfaced-mounted, and wiring is exposed for speedy circuit tracing and servicing. The electrical circuits are arranged and connected so that emergency service work can be done on one transmitter while the other is on the air, even to changing the power amplifier tube of either transmitter. All fuses are of visual indicating type, grouped on the control panel for quick identification. High-power circuits are doubly protected by high-speed overload relays backed up by thermal circuit-breaker switches. Similar circuit-breaker switches connect water-cooler, blowers, filament, and low-power circuits to the power line.

Tube changing in the TT-5A can be accomplished in a matter of seconds, thanks to the convenient "open" arrangement of the components. Even the RCA-8D21 water-cooled power amplifier tube, with its unusual construction, does not require more than a few minutes to change. When a spare 8D21 tube has been previously assembled to a mounting plate identical to the one in the transmitter, tube and mounting plate can be quickly replaced as a single unit, greatly simplifying the procedure. This mounting plate assembly is shown in Figure 6-7.

In the TT-5A, the need for replacing tubes and other components should be very infrequent because the power dissipated in the circuits and the applied operating voltages are well below the conservative ratings of each component. However, transmitter failures are never beyond the realm of possibility, and their importance is directly related to the complexity of the

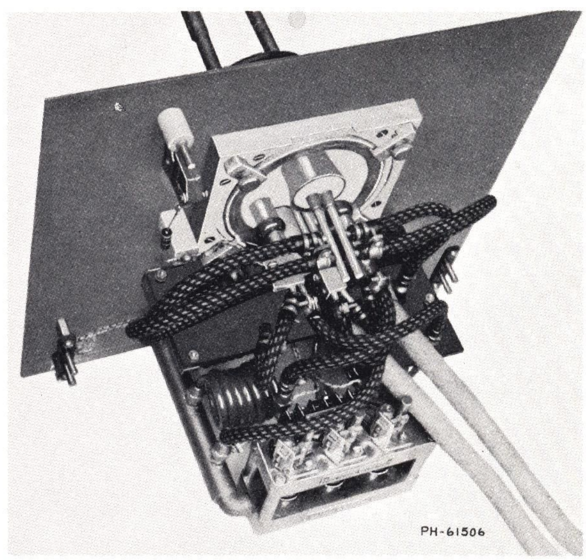


Figure 6-7 - Spare-tube Mounting Plate. With a spare tube mounted on this plate, and with most water connections made, the assembly is ready for quick insertion.

transmitter. In some instances, the completion of emergency repair work may be followed by retuning of the entire picture channel -- a laborious and time-consuming task which increases in size as the number of broad-band stages involved. Lack of a simple and reliable method of tuning up, therefore, may mean loss of valuable program time. The logical step is to provide effective means for quick restoration of service to be applied when failure occurs. One of these measures is the quick-picture-tuning method to be described.

PICTURE TUNING

As previously mentioned, the power amplifier of the RCA TT-5A is the only broad-band stage in the transmitter. All r-f stages, up to and including the grid of the final stage, are tuned by means of meter observations in 30 to 45 seconds. (In the case of the channel 6 to 13 transmitter, this may be somewhat longer unless the two extra stages have previously been neutralized.)

The video stages are fixed and need no tuning. The operator can follow either of two procedures. If time is limited and he wishes to get on the air as quickly as possible, he will switch in a "tune-up" crystal provided for this purpose in the oscillator (approximately 1.6 mc higher in frequency than the normal crystal), tune up the r-f chain, *tune the PA output by meter readings*, and adjust the output coupling to give pre-determined meter readings. The purpose of the tune-up crystal is to allow the PA to be tuned up so that its pass-band is symmetrical about the carrier. The normal crystal is then switched in, the exciter stages touched up again for the normal frequency, and the excitation voltage on the final stage adjusted. The transmitter is then ready for modulation, and the tuning will be found close enough to give a good picture. For more accurate settings, the video sweep is fed into the picture input of the transmitter (after switching the transmitter to "sine-wave" modulation) and the signal is demodulated by the "sweep diode" of the WM-13A. Its output may be presented either on an oscilloscope or the console CRO and will show the band-pass characteristic. All the necessary adjustments to the PA plate may be made by observations of this presentation. In addition, any desired record can be made by transcribing from the scope.

MONITORING

As mentioned before, detected signals from the sideband filter can be fed to the master monitor in the console to provide composite black-and-white pictures as well as wave form displays of the signal being transmitted. Detection of the r-f signals for feeding to the picture tube is performed by the RCA WM-12A Picture Demodulator, while video signals for wave form display are provided by the RCA WM-13A Modulation Monitor.

Both these instruments are high-quality superheterodyne receivers, tunable to any one of the 12 Metropolitan television channels. A stage of r-f amplification, two stages of picture i-f (25.75 mc), a diode-crystal second detector and two stages of video amplification are employed in each instrument. The WM-13A has additional components such as an auxiliary diode-crystal rectifier, two stages of sync amplification and separation, and keyer stages.

The germanium crystal rectifier of the WM-13A, with its input connected to pickup r-f from the transmission line and its output connected through a low-pass filter to the oscilloscope, provides for observation of the transmitter frequency-response characteristics. A single switching system, employing a remotely controlled relay, allows the selection of either the crystal or the superheterodyne outputs. Synchronized by vertical sync pulses separated from the composite video signal, the keyer of the WM-13A produces a rectangular pulse of a duration equal to the flyback time of the oscilloscope sweep. This pulse is used to stop the local oscillator of the WM-13A for the pulse duration; and since the oscilloscope sweep frequency is half the picture frame frequency, the resultant display on the oscilloscope screen will be a horizontal base line referencing zero output from the transmitter.

SMALL SPACE REQUIREMENTS FOR THE RCA TT-5A

The entire television transmitter is housed in eight steel frames bolted to a base frame. The base structure is divided so that the eight cabinets can be placed either in a straight line or in several possible U-arrangements. A bulk wiring material kit is supplied as part of the equipment, and cabinet interconnecting wires are designed to be run through the base structure to the various, conveniently located, terminal boards. Only external connections need be considered when planning the installation, as long as continuity is maintained along the front surface of the cabinets comprising the transmitter.

Individual air-inlet openings with removable filters near the bottom of the rear door of each compartment assure a clean, dust-free air supply to the interior of the transmitter. Small blowers, installed inside the cabinets,

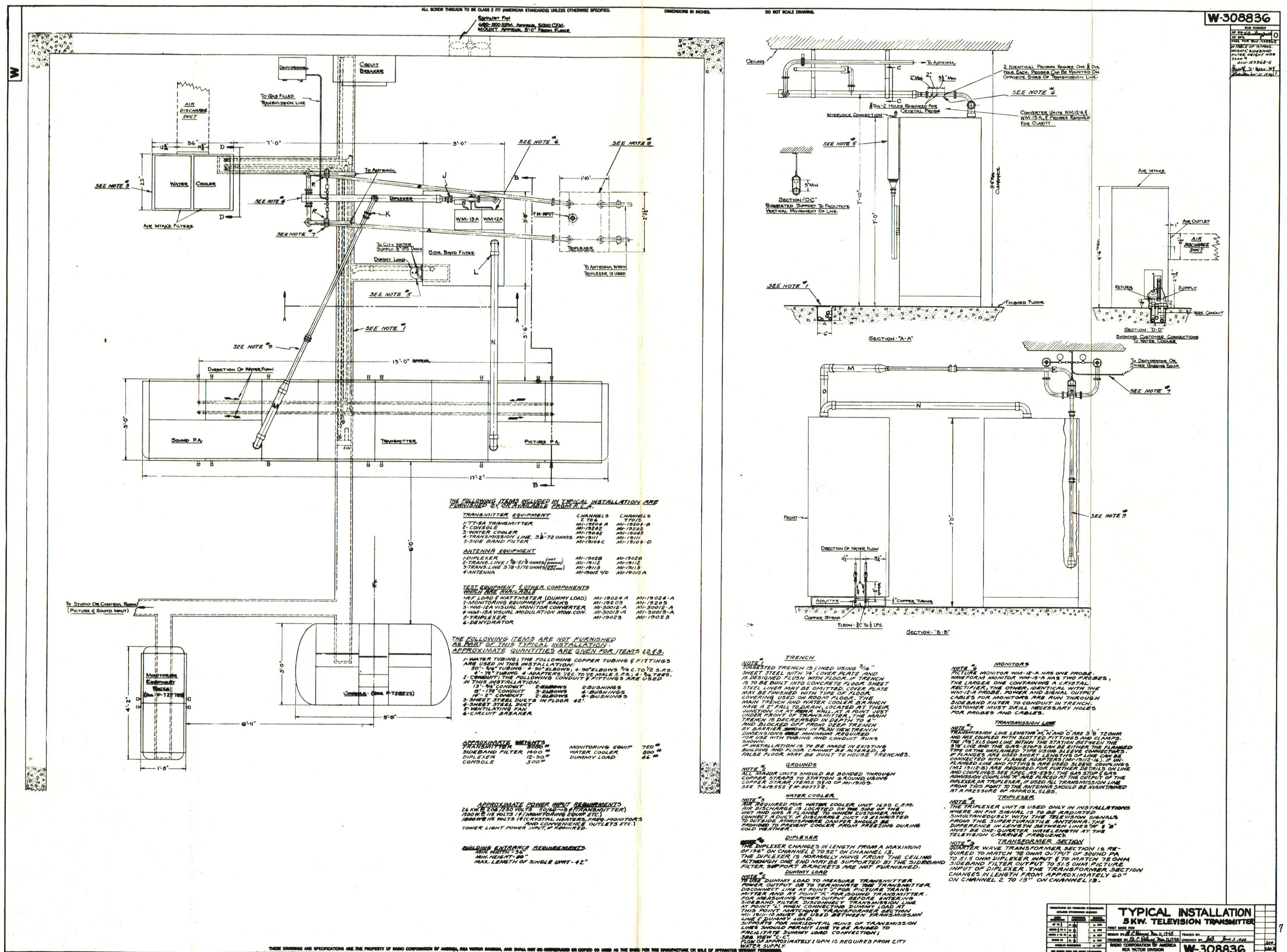


Figure 6-8 - TT-5A Television Transmitter, Typical Installation (W-308836)

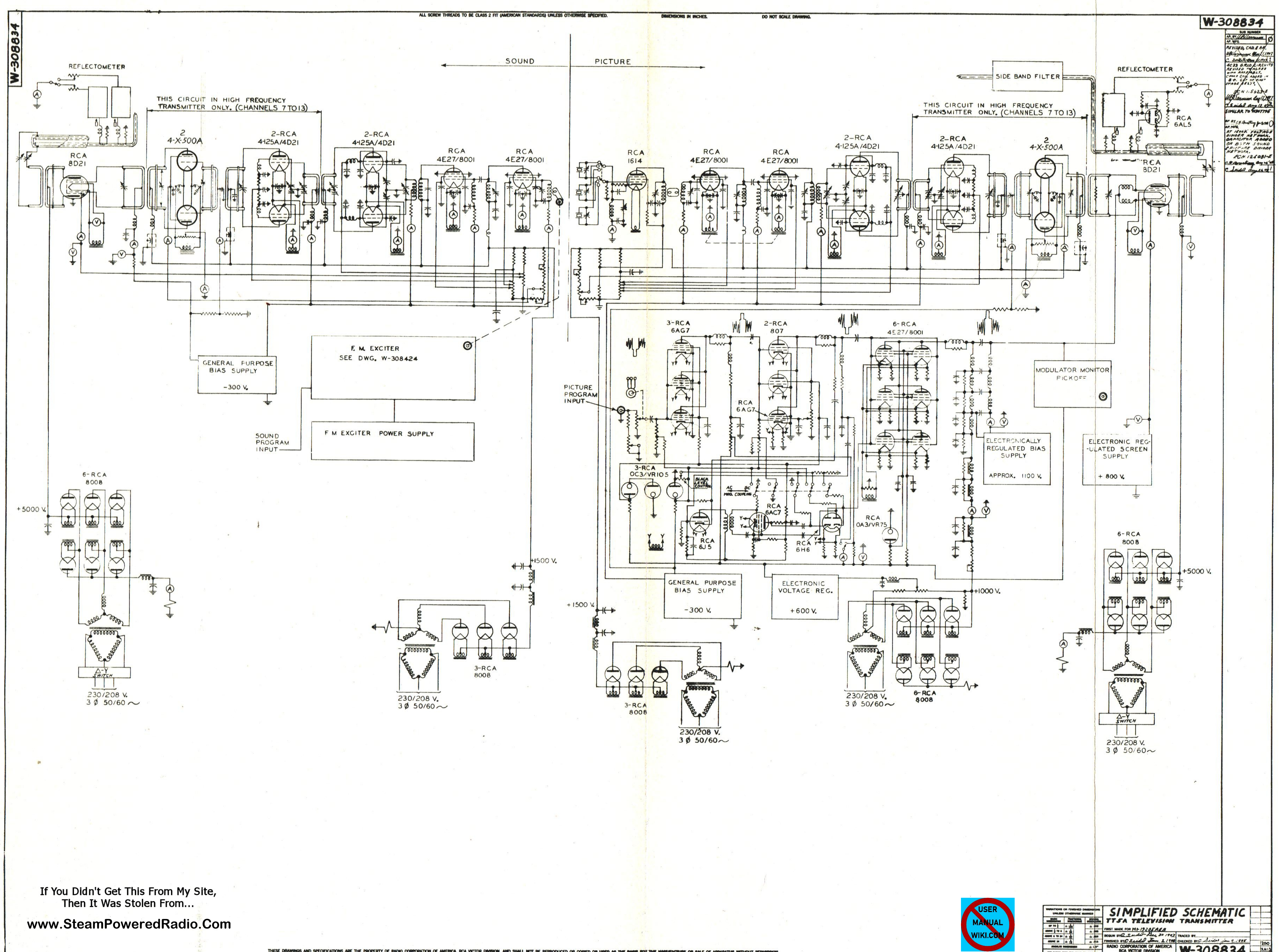


Figure 6-9 - TT-5A Television Transmitter, Simplified Schematic Diagram (W-308834) supply adequate ventilation, warm air being expelled through louvres in the top plates. For ease in shipment, handling, and installation, the RCA TT-5A transmitter is packaged in relatively small units. The largest unit, uncrated, measures 25 x 38 x 80 inches and weighs about 600 pounds.

WATER CIRCULATOR

The water-circulating system is furnished complete as a unit, and may be located remotely from the transmitter in an adjoining room or on the floor below. The unit is a closed system and therefore does not require an external water supply. Connections to each PA cabinet can be made via either a trench terminating beneath the transmitter, or through access holes in the rear of the PA cabinets. Circuit-breaker type switches are used in the feed circuits for the water cooler as well as for the ventilating blowers.

Two sizes of water circulators are now available for use with the TT-5A transmitter. The larger size, MI-19041, will furnish up to 6.0 gpm for the transmitter proper, plus 4.5 gpm maximum for a dummy load, and will operate at 50 cycles as well as 60 cycles with only very minor modifications. The smaller, and newer, circulator, MI-19045, will furnish up to 7 gpm for the transmitter, and is designed to operate only on 60-cycle supply. This reduced water-flow rating is justified, since the new dummy loads operate on the "heat exchanger" principle and, therefore, use the standard mains for water supply. The latter unit is completely encased and is somewhat quieter in operation than the larger unit. The following tabulation shows the relative ratings and sizes of the two units.

	MI-19041	MI-19045
Rated water delivery, gpm	10.6	7.0
Rated water pressure, psi	75	80
Pressure regulation, psi	± 2	-2 +5
Rated heat dissipation, kw	15.2	10.0
Overall size, inches	68 x 34 x 76	54 x 25 x 36
Weight, lbs.	1300	650

MEASURING EQUIPMENT RACKS

Figure 6-10 shows the measuring equipment cabinet racks which are furnished, as factory-wired cabinets, for housing the more important auxiliary transmitter equipment.

The left-hand rack contains the auxiliary sound equipment, consisting of the following major units:

GR-1170-A	FM Frequency and Modulation Monitor
RCA-36A1	Limiting Amplifier
MI-4645	Sound Jack Panel
MI-19126	Pre-emphasis Network
RCA-BA4A	Monitoring Amplifier

The right-hand rack contains the auxiliary video equipment, consisting of the following major units:

WP-33A	Console Power Supply
TA-5B	Stabilizing Amplifier
530-C	TA-5B Regulated Power Supply
MI-26245	Video Jack Panel
MI-8262	Power Supply for WM-12A and WM-13A
WF-49A	Carrier Frequency Meter
WF-50A	Carrier Frequency Monitor

TECHNICAL SPECIFICATIONS

TRANSMITTER

	SOUND	PICTURE
Types of emission	A3	A5
Frequency range	Channels 2 to 13 incl. (54 to 216 incl.)	
Power output	2 to 2.5 kw	4 to 5 kw (peak)
R-F output impedance	72 ohms	72 ohms
Carrier frequency stability	± 0.002%	± 0.002%
Modulation capability	± 40 kc	90%
Method of modulation	Reactance tubes	Amplitude, PA grid
Input impedance	600 ohms	72 ohms
Input voltage	+ 10 ± 2 db for ± 40-kc swing	1 volt, peak to peak

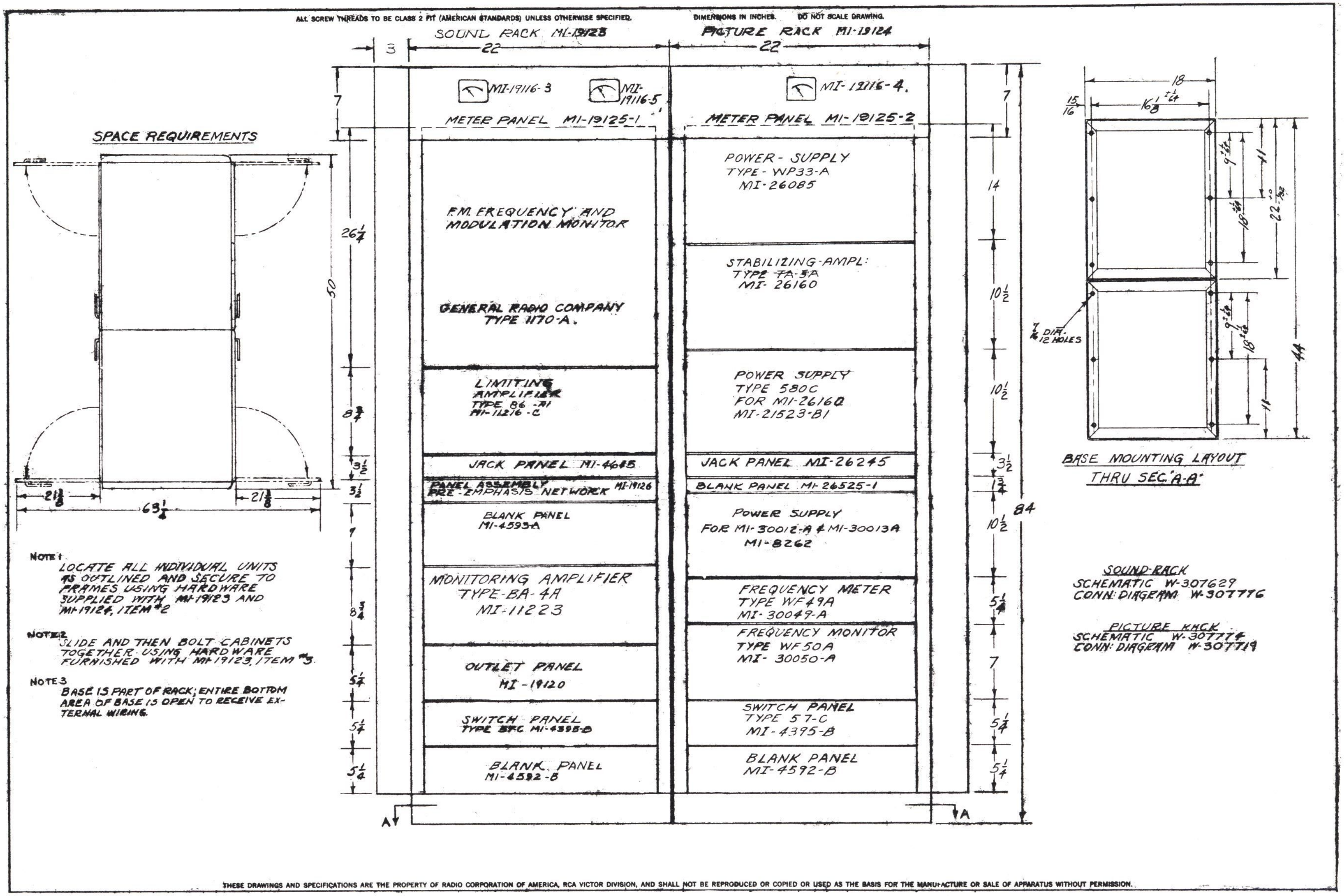


Figure 6-10 - Monitoring Equipment Racks, Outline Dimensions (P-727789)

TRANSMITTER *(Continued)*

	SOUND	PICTURE
Frequency response	* Uniform within ± 1 db from 30 to 15,000 cycles	** 2 db at 0.5 mc 2 db at 1.25 mc 2 db at 2 mc 2 db at 3 mc 3 db at 4 mc
Audio-frequency distortion ***	50 to 100 cycles 1.5% 100 to 7500 cycles 1.0% 7500 to 15,000 cycles 1.5%	
Noise level:		
F-M noise, below ± 25-kc swing	60 db	Less than 5% of peak-to-peak signal amplitude
Amplitude noise, rms below carrier	50 db	

* *For pre-emphasized response, the pre-emphasis filter (MI-4926-A) is to be inserted in the 600-ohm audio input line.*

** *Maximum variance with respect to the idealized rectified vestigial sideband response.*

*** *Distortion and noise are measured following a standard de-emphasis network.*

Transmitter Dimensions:

Length . . . . 208 inches
Height . . . . 34 inches
Depth (overall, incl. door handles) . . . . 38 inches

Weight (approximate)

Transmitter (8 cabinets plus 2 PA cabinets) . . . 3000 lbs.
Console . . . . 600 lbs.
Water Circulating System . . . . { 650 lbs. / 1300 lbs.

Power Requirements

Transmitter:

Line voltage . . . . 208/230 volts, 3-phase, 50 or 60 cycles
Power consumption . . . . 24,000 watts
Power factor 85%

Console, Crystal Heaters, etc.:

Line voltage . . . . 115 volts, single phase, 50 or 60 cycles
Power consumption (approximate) . . . . 600 watts

VESTIGIAL SIDEBAND FILTER

Lower sideband attenuation . . . . 20 db or greater at frequencies below channel

Frequency range
Low-frequency unit . . . . Channels 2 to 6 inclusive
High-frequency unit . . . . Channels 7 to 13 inclusive

VESTIGIAL SIDEBAND FILTER *(Continued)*

Maximum power transmission (either unit)	5 kw
Insertion loss	3.38% at 100 mc (varies as square-root of frequency)
Input impedance	51.5 ohms
Output impedance	51.5 ohms
Dimensions: (unit will be ceiling-mounted):	
Length	92 to 121 inches, depending on channel
Width	11-1/2 inches
Height	7-3/4 inches
Weight (approximate)	200 lbs.

R-F LOAD

Impedance	51-1/2 ohms
Video standard-wave ratio	1.1 maximum
Frequency range	Channels 2 to 13, 50-216 mc
Power dissipation (maximum)	Output of 5-kw transmitter (3-kw black-level power)
Dimensions:	
Height	33-1/2 inches
Width	5 inches
Depth	5 inches
Weight (approximate)	46 lbs.

RCA TELEVISION TRANSMITTERS

TT-500A AND TT-500B

INTRODUCTION

Two low-power television transmitters have been designed which permit high-definition picture transmission at the power levels and low financial outlay required for the smaller metropolitan areas.

The TT-500A and TT-500B transmitters are for low-band (channels 2 to 6) and high-band (channels 7 to 13) respectively. Since the tubes and circuits of these two types are somewhat different, they will be taken up separately.

The physical specifications and electrical performance, however, are largely the same for both types and, wherever possible, are listed for both types. The use of high-gain beam power tubes throughout these equipments makes possible a low tube-complement cost and, at the same time, gives greatest simplicity in tuning operations.

The use of single-ended r-f circuits in these equipments makes possible some simplifications in circuit layout. The grounded type of circuit also removes the need for a "balun" between amplifier and transmission line.

Control circuits in visual and aural units are separate, so that either portion may be used independently of the other.

The complete aural and visual transmitter combination is 56 inches wide, 34 inches high, and has a depth of 31 inches over the door handles. Detailed dimensional information is given in Figure 6-19.

The external appearance of these two equipments is essentially the same and is shown by the photograph Figure 6-11.

A typical 500-watt transmitter room arrangement is shown in Figure 6-12.

Figure 6-11 - TT-500A or TT-500B Television Transmitter and MI-19266 Console

TT-500A TRANSMITTER (CHANNELS 2 TO 6)

VISUAL PORTION - The r-f and driver stages are conventional narrow-band circuits which may be tuned quickly and accurately by meter indications. High-level video modulation is applied to the grids of the visual power amplifier tubes. These tubes, two RCA-4-250A/5D22, are parallel-connected and their output circuit is the only broad-band r-f circuit in the equipment. Figure 6-13 shows the tube line-up and circuit for this equipment.

The visual carrier frequency is established by direct crystal control. The crystal unit, a type TMV-129C temperature-controlled unit, operates at one-half the visual carrier frequency.

The video amplifier and modulator include three stages. Two type RCA-6AG7 tubes are used as high-quality voltage amplifiers to excite the grids of three type RCA-307 beam-power modulator tubes. Suitable high-frequency compensation is applied to the plate load circuit of each stage to provide uniform gain and phase characteristics over the entire video-frequency band.

A clamp-type d-c restorer circuit is used in the grid circuit of the modulator stage. The clamp circuit employs a sync separator (RCA-6C4), a pulse amplifier and inverter (RCA-6C4), and a restorer tube (RCA-6AL5). These tubes are actuated by the sync pulses to generate a half-sine-wave pulse of about two microseconds duration immediately following each horizontal sync pulse. The generated pulse and its inverted self are applied to the restorer diodes,

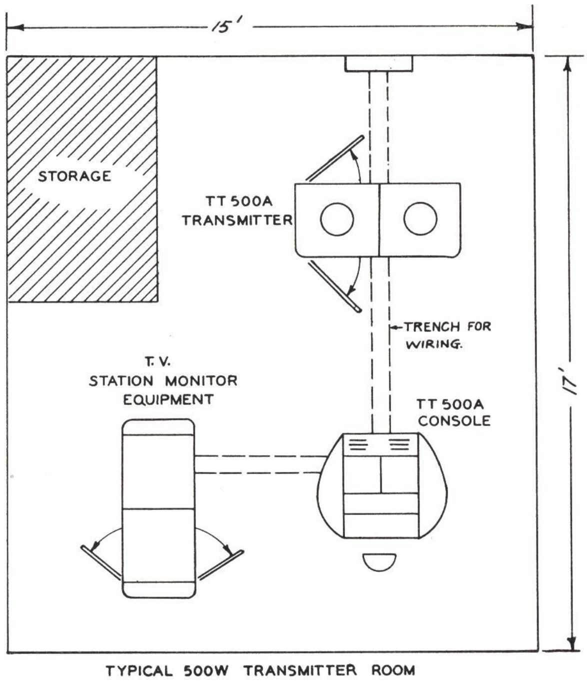


Figure 6-12 - Typical 500W Transmitter Room

and during the resulting conduction period the modulator bias is set to the correct value for the blanking pedestal level.

An amplifier coupling switch is provided to disable the clamp circuit just described, when making tests with other than RMA picture signal input to the modulator. The AC position is used for sine wave, square wave, or sweep modulation, while the d-c position serves only for composite picture signal input.

A variable-gain sync expander tube (RCA-6AC7) is connected parallel to the second video stage. This tube pre-emphasizes the sync portion of the picture signal in order to make up for a slight compression of sync which occurs in the modulator stage and in the r-f modulated amplifier stage.

A type RCA-6V6-GT tube samples the output of the video modulator and provides 2 volts of video to operate the master monitor in the console.

Coupled to the r-f transmission line inside the cabinet is the reflectometer unit, which provides continuous monitoring of the relative peak-power output; in addition, when rotated 180 degrees by a front-panel knob, the ratio of the reflectometer readings in the two positions is the reflection coefficient at the antenna transmission line connection.

Figure 6-13 outlines the fundamental video modulating circuits of the TT-500A. In this transmitter the drop across the modulator load resistance is the total grid bias for the R-F Power Amplifier. This scheme of direct coupling between stages necessitates inverted operation of the modulator power supply, as shown in Figure 6-13.

The variable inductance in the plate circuit of the R-F Power Amplifier, together with the distributed capacitance of the tubes, constitutes the primary circuit of the overcoupled output circuit. The coupling capacitor is adjustable, to permit variation of the coupling coefficient between this primary circuit and the secondary resonant circuit. The secondary circuit includes the antenna transmission line as a load. A variable capacitor, in shunt with this load, permits variation of the effective series-resistance component to obtain optimum secondary "Q".

AURAL PORTION - The RCA FM exciter, which has been highly successful in the FM broadcast field, is used in the aural portion of the TT-500A. This exciter drives a single RCA-4-125A/4D21 doubler stage, which in turn drives the final PA using two RCA-4-125A/4D21 tubes in parallel connection. All the circuits in this unit are easily and quickly adjusted by means of meter indications.

The aural carrier frequency is automatically adjusted by comparison with oscillations of a temperature-controlled crystal unit, RCA type TMV-129G.

Figure 6-14 is a simplified schematic diagram of this equipment, showing the tube line-up and basic circuit.

TT-500B TRANSMITTER (CHANNELS 7 TO 13)

VISUAL PORTION - The visual carrier frequency in this unit is established by direct crystal control. The type TMV-129C temperature-controlled crystal unit operates at 1/36 the output frequency. Following the low-power frequency-multiplication stages, an RCA-4X150A doubler stage drives the final high-level modulated PA stage consisting of four RCA-4X150A tubes in parallel.

Figure 6-15 shows the tube line-up for the TT-500B. Here, as in the RCA TV Transmitters, high-level grid modulation is applied in the final R-F Power Amplifier stage. Only one r-f circuit, the PA output circuit, handles modulation components.

In this transmitter, as in the TT-500A, the

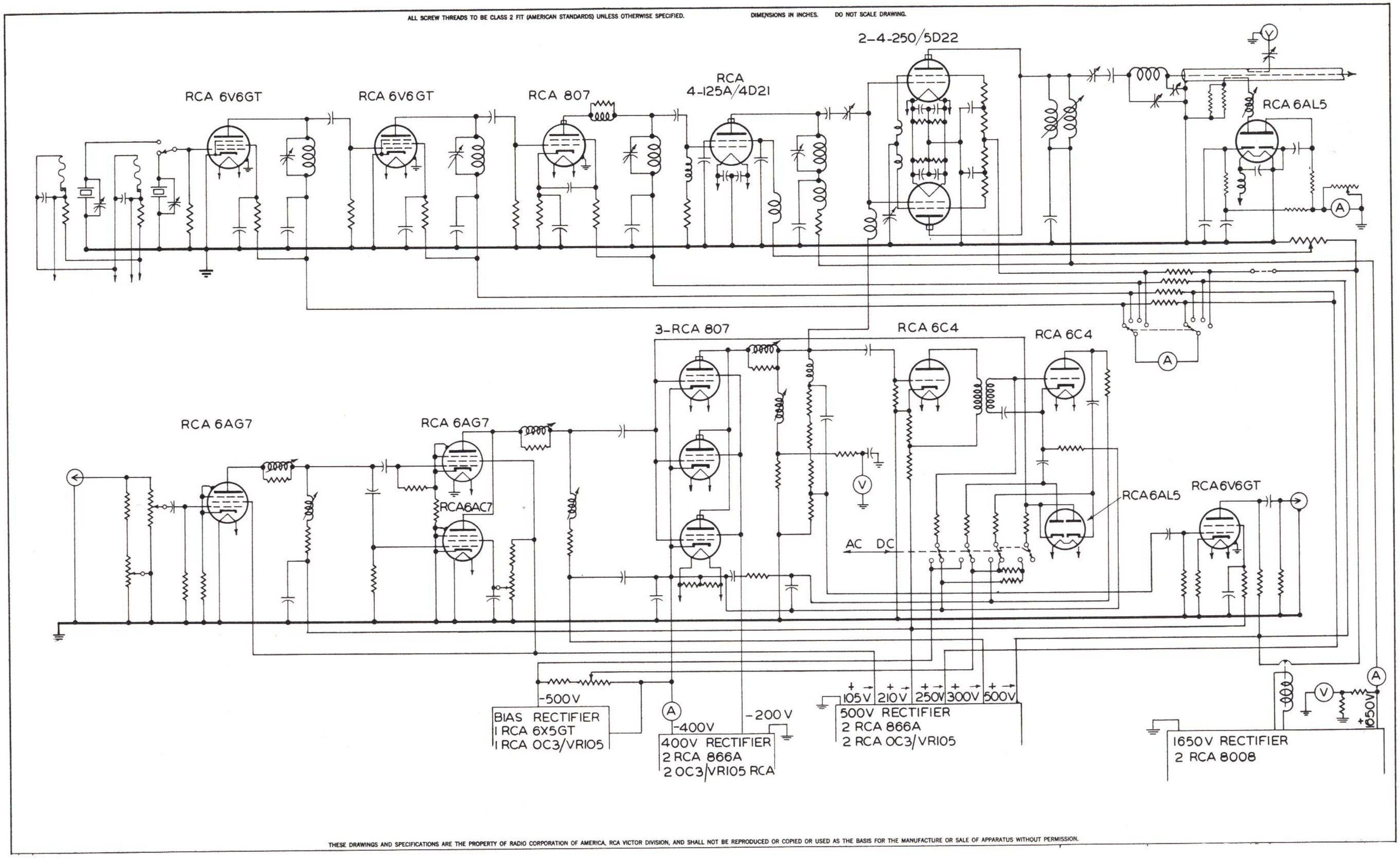


Figure 6-13 - TT-500A Transmitter, Visual Portion, Schematic Diagram (T-619060)

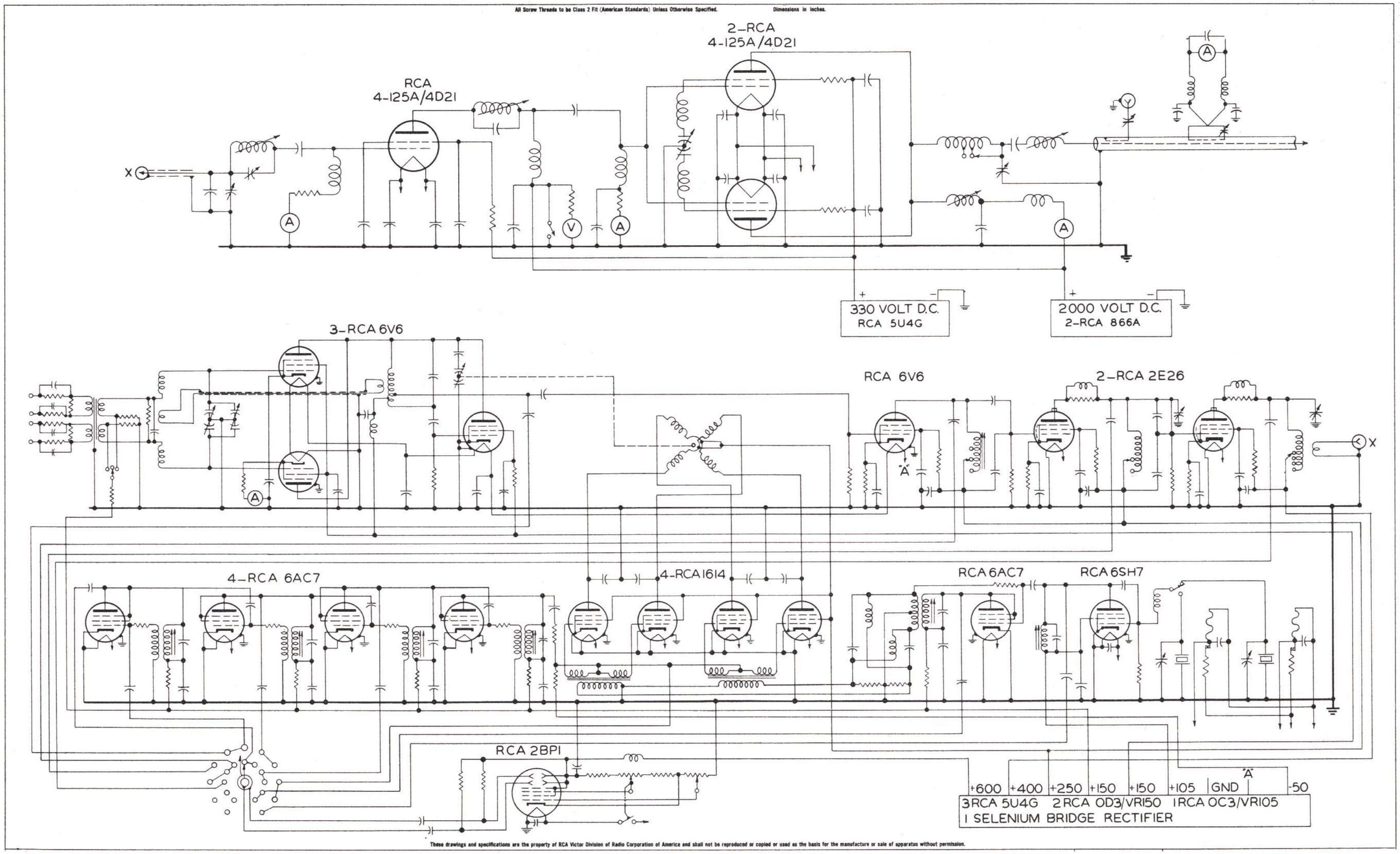


Figure 6-14 - TT-500A Transmitter, Aural Portion, Schematic Diagram (T-618383)

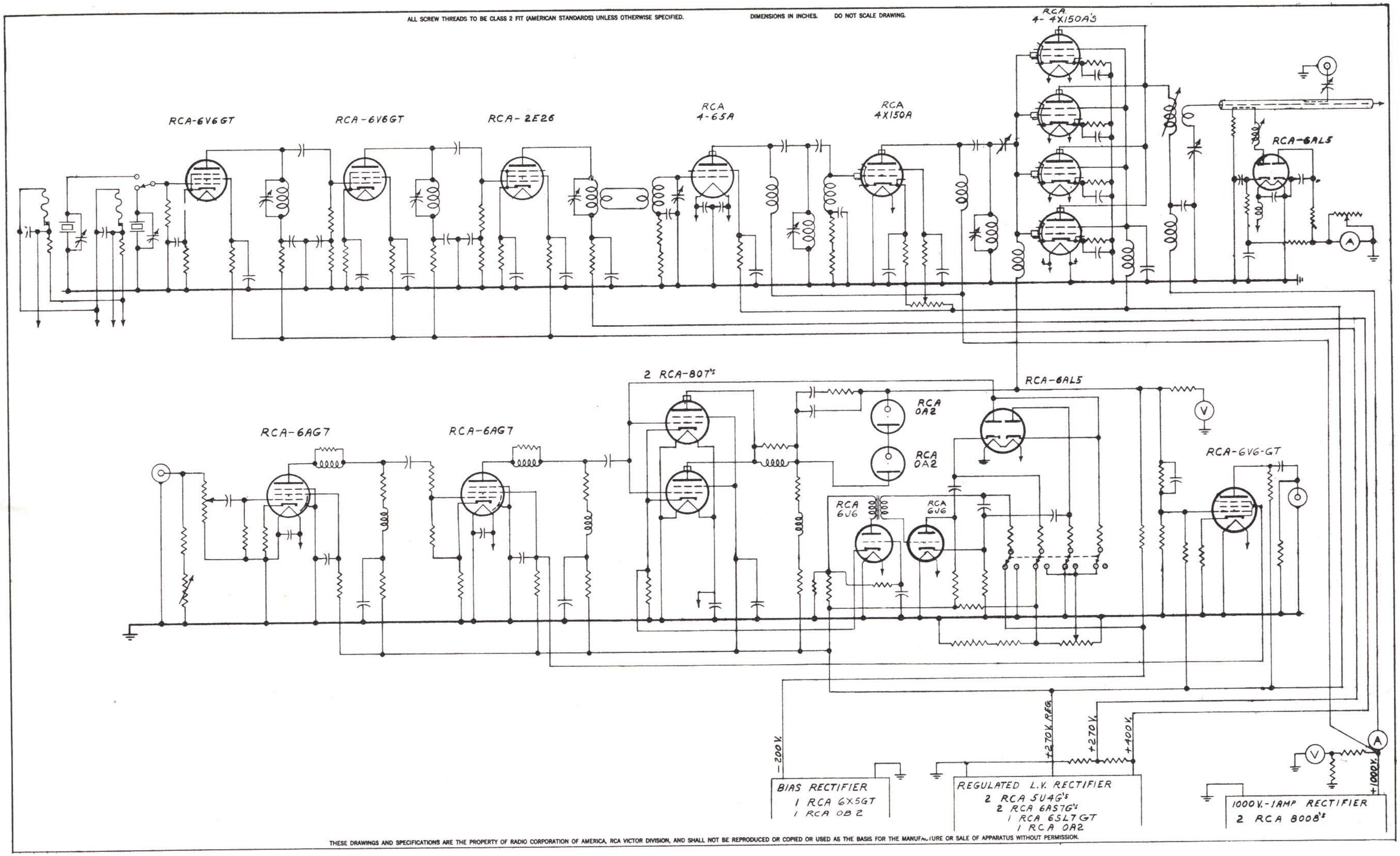


Figure 6-15 - TT-500B Transmitter, Visual Portion, Schematic Diagram (T-619083) output-circuit primary is tuned by distributed capacitance, the variable element being the inductance. A novel, collapsible, coaxial bellows arrangement is the inductive element. The over-coupled secondary is a high-impedance coaxial section. Despite the physical differences necessitated by the higher frequency, the type of circuit is equivalent to the output circuit of the TT-500A.

A three-stage video amplifier modulator is used in this transmitter. Two stages of voltage amplification, using RCA-6AG7 tubes, are employed ahead of the modulator stage. The modulator tubes are two type RCA-807's, the output of which is coupled to the grids of the final r-f power amplifier. Direct coupling to the point of modulation is made through two bucking bias glow tubes. These tubes provide a constant negative bias voltage which is added to the modulator power supply and load resistance drop to give the correct range of bias voltage variations to the modulated r-f stage.

A novel type of sync expansion has been incorporated in this modulator. A single germanium-crystal diode unit is connected between the cathode of the modulator and the cathode of the second video stage, and is so biased as to conduct only during sync pulses. Its conduction develops a voltage pulse across the cathode resistor of the second video stage during the sync pulse. This developed voltage is regenerative and adds to the total sync output.

A clamp-type d-c restorer circuit is used in the grid circuit of the modulator stage. The clamp circuit employs three sections of RCA-6J6 tubes. Two sections are used in the sync separator and the third section serves as a pulse amplifier and inverter. The d-c restoration diode is an RCA-6AL5.

Two reflectometer units are included, one each in the transmission line of the visual and the aural units. These instruments contribute the dual feature of continuous power-output indication and ability to quickly determine the condition of transmission-line match at the transmitter output coaxial line.

AURAL PORTION - The circuit diagram Figure 6-16 shows details of the aural transmitter. Except for the FM Exciter, this unit is the same as visual unit.

ASSOCIATED EQUIPMENT

CONSOLE - The monitoring console furnished with the 500-watt transmitters provides push button switching facilities for checking the quality of picture and sound signals at various points in the transmitters. This function is invaluable for maintaining highest quality transmission, since it permits immediate localization of any defect that may appear in the transmitted program.

The standard RCA TM-5A master monitor unit is used for picture and wave form observation. Its kinescope and CRO tube input circuits may be independently switched to the different circuits by means of push buttons. Push button switching is also employed at the input of the VU-meter and the monitoring amplifier input.

A gain control for both the visual and the aural signal input to the transmitter is conveniently located on the panel of the console.

All monitoring circuits are readily available on the jack panels of the monitoring equipment racks, thus facilitating other than routine tests, and making possible the use of monitoring equipment for other than strictly transmitter testing.

Outline dimensions for the console are given in Figure 6-17.

MONITORING EQUIPMENT - Since the monitoring requirements are the same for a low-power as for a high-power station, the same set of monitoring equipment is furnished with 500-watt transmitter as with the higher-powered RCA Television Transmitter.

The standard monitoring equipment rack includes program limiting and monitoring amplifiers for the aural transmitter, and a stabilizing amplifier for incoming video signals.

Complete frequency and modulation monitoring units are provided for the aural and visual transmitters.

Visual monitoring equipment includes the RCA WM-12A and WM-13A units. The WM-12A demodulates the output of the vestigial sideband filter in the same way as a receiver, giving the necessary video output to operate the picture kinescope in the console master monitor. The WM-13A gives either of two output signals which display the synchronizing wave form or the sweep response characteristics, at the option of the operator.

All test equipment terminals, and the terminals of signal circuits to the various pieces of audio and video equipment, are brought to jacks on the monitoring equipment racks. By the use of patch cords and jumper plugs, great flexibility is attained in the connection of equipment.

R-F LOAD AND WATTMETER - A dummy load, MI-19024-B,

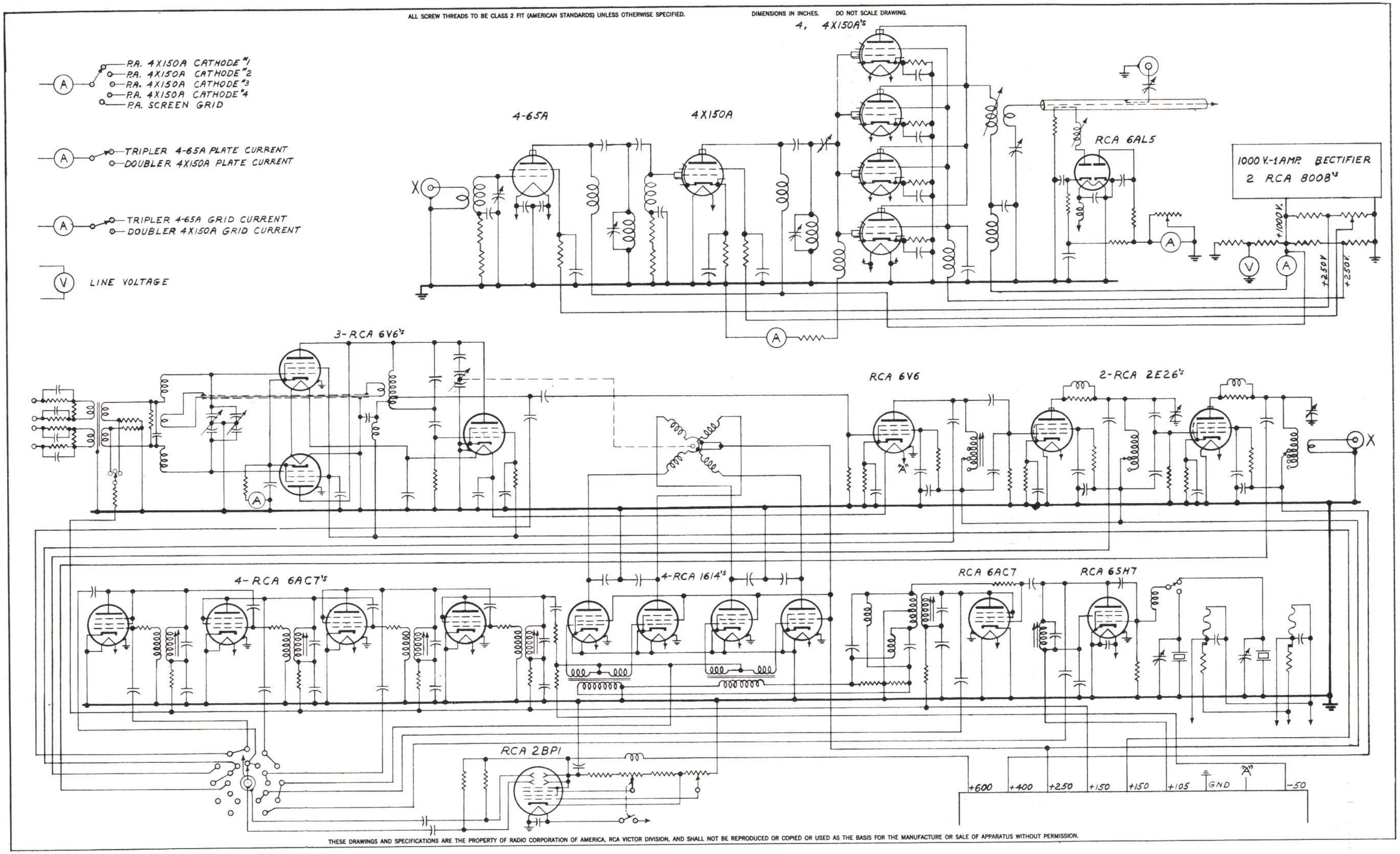


Figure 6-16 - TT-500B Transmitter, Aural Portion, Schematic Diagram (T-619575)

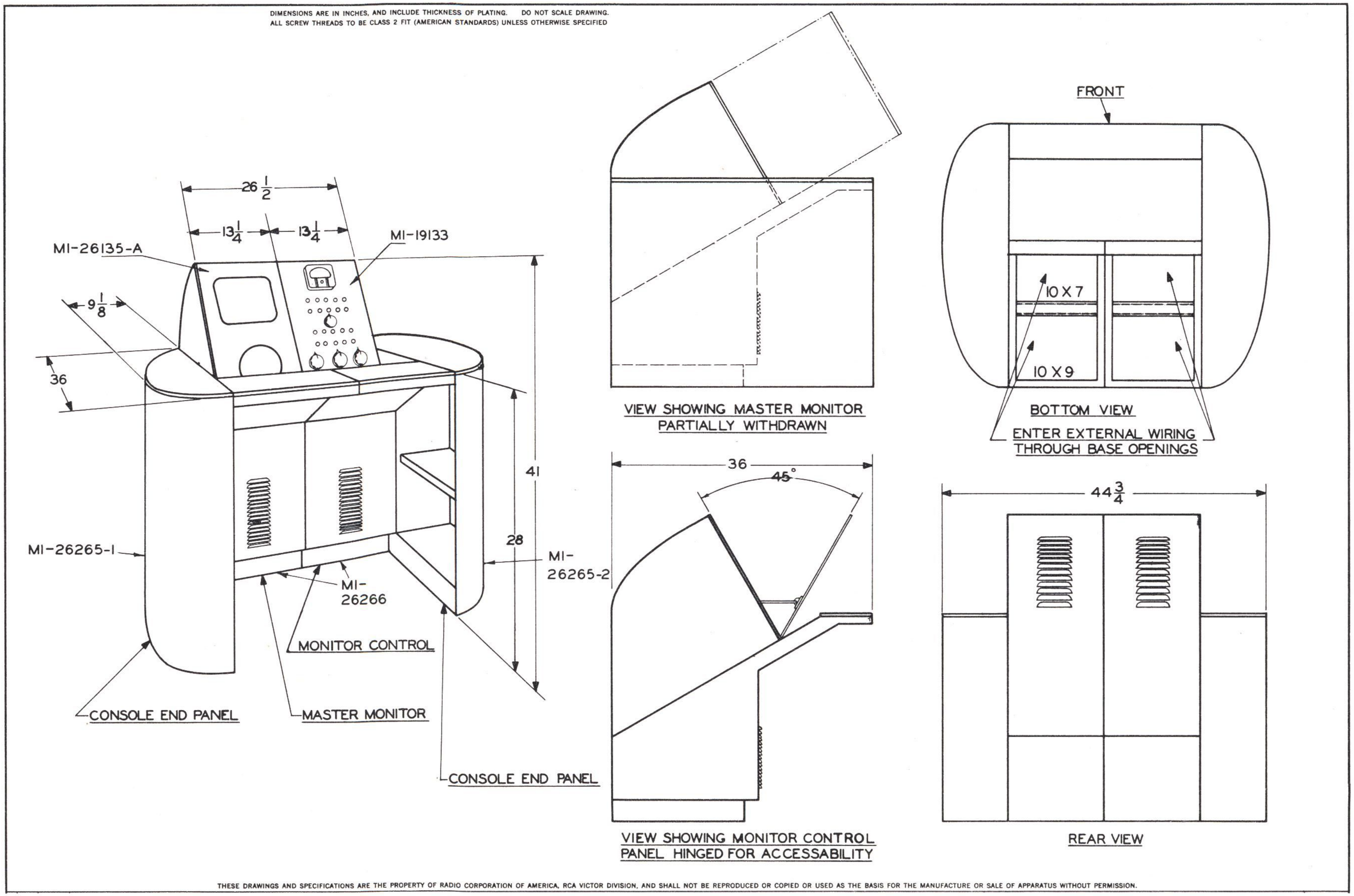
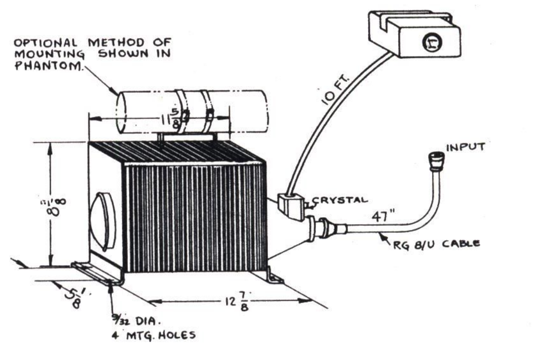


Figure 6-17 - Console for 500-watt TV Transmitter, Outline Drawing (P-738303) properly terminates the output of either the aural or visual transmitter, and gives a measurement of the average r-f power. A coaxial coupling is provided for making connection to standard 1-5/3-inch, 51-5-ohm transmission line.

The internal resistance element of the r-f load is liquid-immersed, and the heat therein developed is conducted to the external radiating fin structure.

Power output is measured by a calibrated crystal detector and current-indicating instrument which is coupled into the r-f feed line. The time constant of the meter circuit is such as to give an indication of average power of a black television picture, as required by FCC.

This load is shown in the drawing Figure 6-13.



NAME	R F LOAD & WATTMETER 500 WATTS
MI	19024 B
FREQUENCY MC	54-216
WEIGHT LBS	20
R F INPUT	1 5/8 51 1/2 Ω
RF OUTPUT	—
NON-RF CONNECTIONS	—
TYPE OF MOUNTING	HORIZONTAL SURFACE WITH FREE AIR CIRCULATION. USE A FAN IF AMBIENT IS OVER 100 F. NOTE OPTIONAL MOUNTING.

Figure 6-18 - 500-watt R-F Load and Wattmeter, MI-19024-B, Outling Drawing (M-450447)

PERFORMANCE SPECIFICATIONS

TRANSMITTER

	SOUND	PICTURE
Type of emission	A3	A5
Frequency range { TT-500A	Channels 2 to 3	Channels 2 to 6
Frequency range { TT-500B	Channels 7 to 13	Channels 7 to 13
Power output into transmission line	250 watts	500 watts peak
R-F output impedance	51.5 ohms	51.5 ohms
Carrier frequency stability	± 0.002%	± 0.002%
Modulation capability	± 40 kc	90%
Method of modulation	Reactance tubes	Grid amplitude
Input impedance	600 ohms	75 ohms
Input voltage	+ 10 ± 2 dbm	1 volt peak to peak
Frequency response	** Uniform ± 1 db 30 to 15,000 cycles	* 2 db at 0.5 mc 2 db at 1.25 mc 2 db at 2.0 mc 2 db at 3.0 mc 3 db at 4.0 mc

* *Maximum variation below idealized rectified vestigial sideband response.*

** *For pre-emphasized response, the pre-emphasis filter (MI-4926-A) may be inserted in the 600-ohm audio input line at the most effective point.*

TRANSMITTER *(Continued)*

	SOUND	PICTURE
Maximum audio-frequency distortion ***	50 to 100 cycles 1.5% 100 to 7500 cycles 1.0% 7500 to 15,000 cycles 1.5%	
Noise level		
F-M noise below ± 25-kc swing	60 db	
Amplitude noise, rms below carrier	50 db	
Amplitude variation over one frame of picture		Peak to peak less than 5% of the synchronizing peak level

**** Distortion and noise measured following a standard de-emphasis network.*

POWER LINE REQUIREMENTS

TRANSMITTER

Voltage . . . . 208/230 volts
Phase . . . . single
Frequency . . . . 50/60 cycles
Instantaneous regulation . . . . 5% maximum
Power consumption (approx.) . . . . 3000 watts
Power factor (approx.) 0.85

(For 50-cycle operation, regulating transformer MI-28176 is required in the aural transmitter.)

CRYSTAL HEATERS

Voltage . . . . 115 volts
Phase . . . . single
Frequency . . . . 50/60 cycles
Power consumption . . . . 56 watts

MONITORING EQUIPMENT

Voltage . . . . 115 volts
Phase . . . . single
Frequency . . . . 50/60 cycles
Power consumption (approx.) . . . . 1300 watts

MECHANICAL SPECIFICATIONS

TRANSMITTER

Dimensions (overall)

Width . . . . 56 inches
Height . . . . 34 inches
Depth (including door handles) . . . . 31-1/16 inches

Weight . . . . 2150 lbs. (approx.)
Finish . . . . Two-tone umber grey with brushed chrome trim and fittings

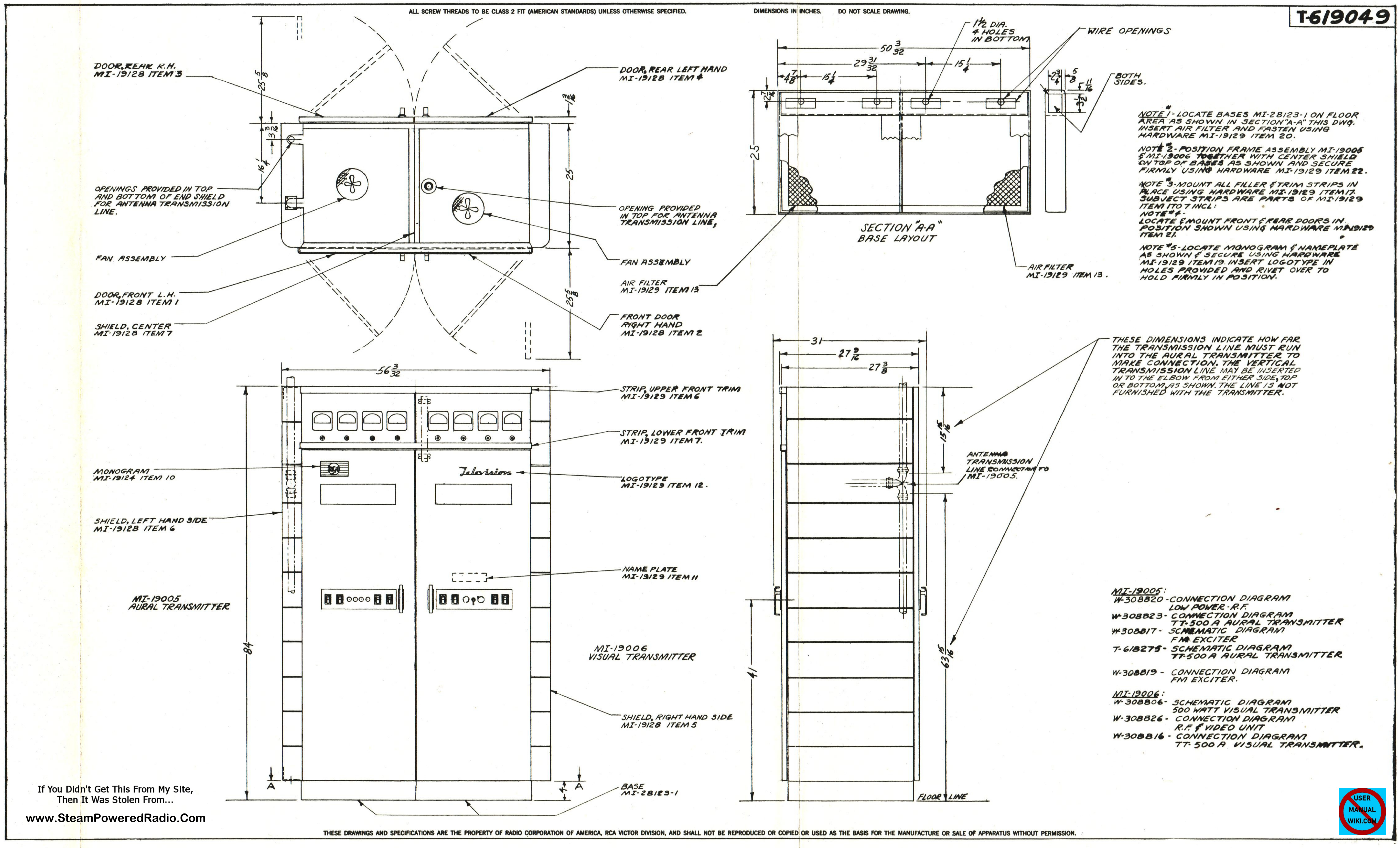


Figure 6-19 - TT-500A Television Transmitter Outline Drawing (T-619049)

TELEVISION TECHNICAL TRAINING PROGRAM

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SECTION VII

TELEVISION ANTENNAS

SECTION VII

TELEVISION ANTENNAS

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TELEVISION TECHNICAL TRAINING PROGRAM

ANTENNA EQUIPMENT

The following notes are a summary of lectures on antenna equipment for television systems. They present, in outline form, the various pieces of equipment required in the television station beyond the transmitter. Each piece is discussed as to its purpose, requirements, basic principles, construction, and performance.

SUMMARY OF ITEMS OF ANTENNA EQUIPMENT

NAME	LOCATION	FUNCTION
Balun (BALanced to UNbalanced)	Part of transmitter	Converts double-ended line to single-ended line and maintains bandwidth.
Vestigial Sideband Filter (VSBF)	Station, behind transmitter	Reduces energy in portion of lower sideband (portion outside channel) in accordance with FCC requirements.
Diplexer	Station, behind transmitter	Permits simultaneous use of a same antenna for visual and aural transmission.
Triplexer	Station, behind transmitter	Permits simultaneous use of a same antenna for FM broadcasting in the 88-108 mc band.
Antennas (Standard Types)	Top of tower	Radiates visual and aural signals as well as FM signal, if triplexing is used.
Antennas (Special Types)	Top of tower	Same as above, except fulfills special requirements as higher gain, simultaneous use of one site for several television stations, directional effects, etc.
Antennas (Combination Types)	Top of tower	Allows FM broadcasting by use of Pylon.
Transmission Line	In station and between station and antenna	Transmits power with minimum reflection and loss.

GENERAL PRINCIPLES

TRANSMISSION LINES

THE INFINITE LINE is a uniform line of infinite length. For practical purposes, a line terminated in its characteristic impedance (also called surge impedance) behaves like an infinite line because there are then no reflections from the far end of the line.

SURGE IMPEDANCE - The surge (or characteristic) impedance of a uniform line is the impedance which terminates any length of the line without causing any reflections.

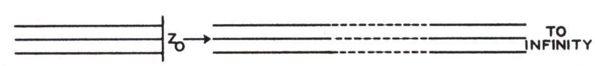


Figure 7-1 - Infinite Line and Surge Impedance

STANDING WAVES - Standing waves on a transmission line are caused by reflections from a mistermination at the far end or by discontinuities on the line itself. The reflected wave is alternately in phase and out of phase with the incident wave. Voltage at a point on the line measures less than the incident wave if the reflected wave is out of phase with the incident wave; it measures more than the incident wave if the reflected wave is in phase with the incident wave.

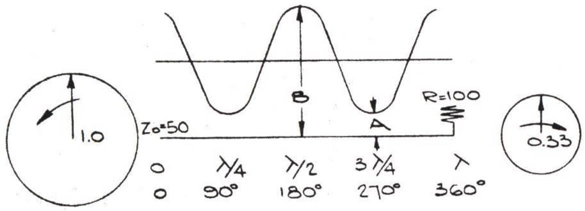


Figure 7-2 - Standard Waves on Transmission Line

VOLTAGE STANDING WAVE RATIO (VSWR) - The VSWR is defined as the ratio of maximum-to-minimum volts appearing along the transmission line. These voltage maxima and minima are the resultants of the addition and subtraction, respectively, of the incident and reflected waves. The surge impedance of the line being designated by Z_o and the terminating impedance being called Z, the voltage reflection coefficient K is

$$K = \frac{Z - Z_o}{Z_o - Z}$$

Thus for Z_o = 50 ohms and Z = 100 ohms we have K = 0.33.

If A and B are the minimum and maximum voltages along the line, respectively, then

$$VSWR = \frac{B}{A} = \frac{1 + |K|}{1 - |K|} \; (= 2 \; for \; K = 0.33).$$

From experimental data it is found that the VSWR of the antenna system should be 1.1 or better over the band, to avoid the appearance of echoes or multiple images in the picture.

BANDWIDTH - The bandwidth is the frequency range over which the VSWR is within certain defined limits.

General Principles of Maintaining Bandwidth.

a. *Constant-impedance Network* - This is a parallel-resonant circuit having resistive components in each branch. When

$$R_C = R_L = \sqrt{L/C}$$

the circuit has constant resistance at all frequencies. Such a circuit is used in modulator and sideband filters.

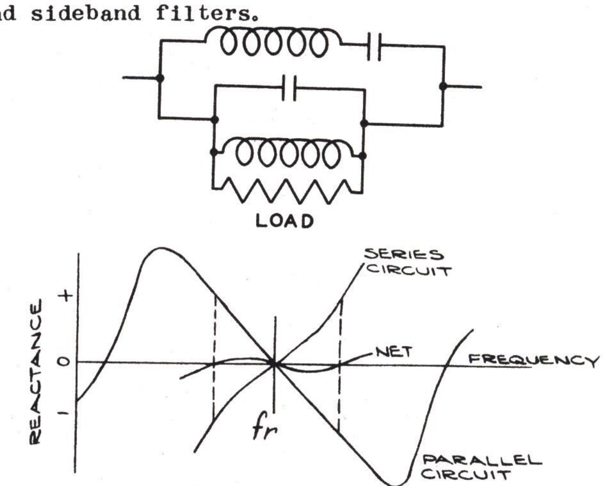


Figure 7-3 - Series-resonant and Parallel-resonant Circuit Combination

b Series-resonant circuits, used in conjunction with parallel-resonant circuits, provide complementary reactances off resonance frequency. This principle is applied in the balun, diplexer, and antenna. It is illustrated in Figure 7-3, which shows the circuit arrangement as well as the series-circuit and parallel-circuit reactances as functions of frequency The overall, or net, reactance is the difference of the series-circuit and parallel-circuit reactances. This net reactance is seen to be nearly zero within the range of frequencies (marked off in dotted lines on the diagram) which defines the bandwidth of the system.

BALUN

This name is derived from the words "BALanced to UNbalanced" which define the purpose and function of the device, namely, to convert the output of the 8D21 tube to a single 72-ohm line, on both aural and visual sides.

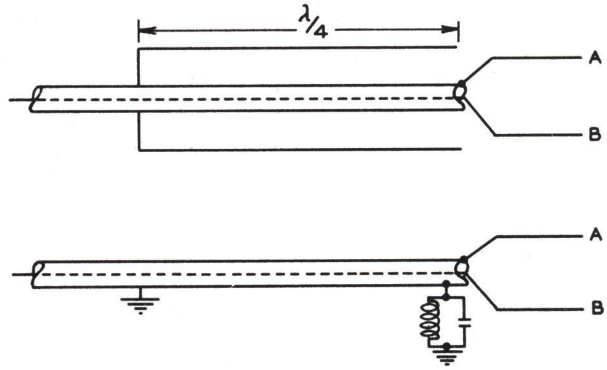


Figure 7-4 - Quarter-wave Transformer

The principle is illustrated in the first diagram of Figure 7-4. This shows a coaxial line, the end of which is surrounded by a quarter-wave sleeve connected to the outer conductor. The equivalent circuit of this "quarter-wave transformer" is shown in the second diagram of Figure 7-4 as a parallel-resonant circuit connected between the outer conductor *A* and ground, but not across the inner conductor *B*.

As a remedy to this unsymmetrical arrangement, the device of Figure 7-5 is used; it is here shown with its equivalent circuit. This is an application of the second principle discussed previously for broadbanding (see paragraph b under the heading BANDWIDTH). The actual circuit shown in Figure 7-5 has been used in the diplexer. For the balun unit, the loads and generator should be interchanged.

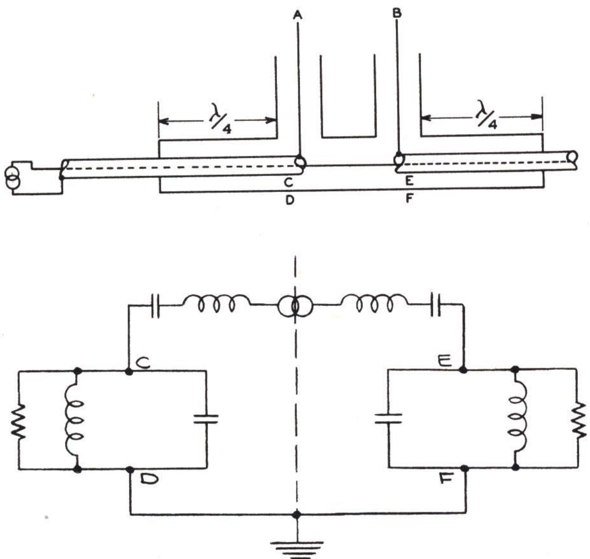


Figure 7-5 - Principle of Diplexer and Balun Units

VESTIGIAL SIDEBAND FILTER

PURPOSE - The vestigial sideband filter reduces the energy in the lower sideband in accordance with FCC requirements, while still presenting constant resistance to the transmitter over the required band.

REQUIREMENTS

(1) 20 db in addition to the average 40 db inherent in typical picture.
(2) Attenuation occurs in 1/2 mc.
(3) Constant VSWR of 1.1, or better, over the band.
(4) Small power absorption.

Typical characteristics of the vestigial sideband filter are shown by the curves of Figure 7-6.

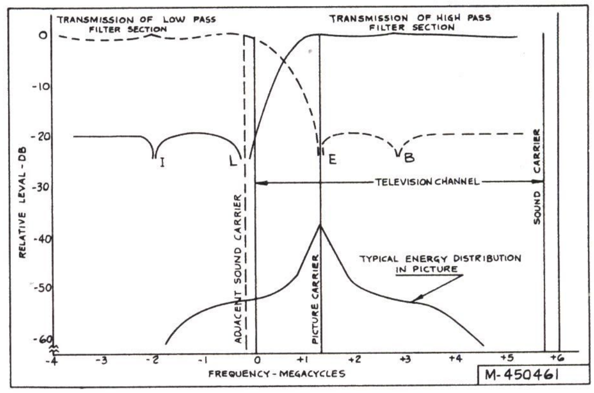


Figure 7-6 - Characteristics of Vestigial Sideband Filter

PRINCIPLE - A simple filter circuit is shown in Figure 7-7. This filter, however, does not satisfy the second of the requirements listed in the preceding paragraph. It is thus necessary to use a four-leg filter network, such as the

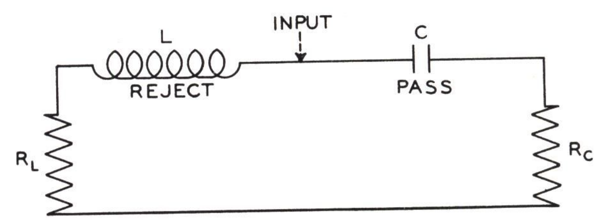


Figure 7-7 - Elementary Filter Circuit
($R_L = R_C = \sqrt{L/C}$)

one shown in the upper diagram of Figure 7-8. Depending on the frequency considered, this network appears with a low-pass or a high-pass characteristic, and is equivalent to the circuits shown in the lower diagram of Figure 7-8.

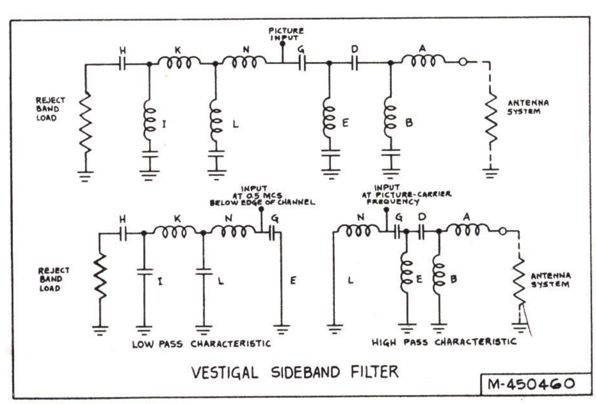
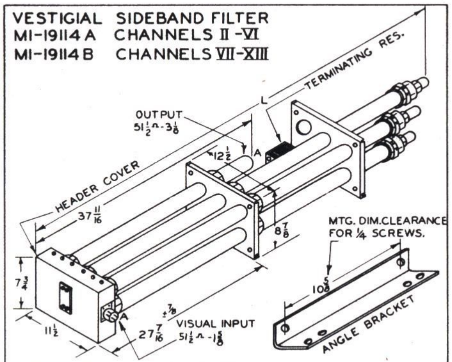


Figure 7-8 - Vestigial Sideband Filter Circuit

CONSTRUCTION - See Figure 7-9 Four shunt lines are made re-entrant to limit the length to a value of 92 to 121 inches, depending on the channel considered. Series capacitors and inductors are line sections less than one-quarter wavelength long. These sections are telescoped into the shunt sections. The entire unit is 92 to 121 inches long, 11 1/2 inches wide, and 7 3/4 inches high, and is designed for ceiling mounting.



CHANNEL	L	CHANNEL	L	CHANNEL	L
II	121"	III	108"	IV	100"
V	86"	VI	80"	VII	110"
VIII	107"	IX	103"	X	100"
XI	97"	XII	95"	XIII	92"

NAME	VESTIGIAL SIDEBAND FILTER
MI	19114A & 19114B
FREQUENCY MC	54-216
WEIGHT LBS.	200
RF INPUT & OUTPUT	51½Ω SEE K-8889742
TYPE OF MTG.	HORIZONTAL SUSPENDED FROM CEILING ABOVE OR BESIDE XMTR.

Figure 7-9 - Vestigial Sideband Filter Construction

PERFORMANCE - All units are preset at the factory and require no field adjustment. The power absorbed in the load resistor never exceeds 30 watts, out of 5 kw, and then only with unusual detail energy beyond 1 1/4 mc. Normally, negligible power is absorbed in a typical picture. The unit meets all requirements outlined previously. Power absorption is 3.37% at 100 mc.

R-F LOAD AND WATTMETER

PURPOSE - The purpose of the R-F Load and Wattmeter is to determine the operating power in accordance with FCC requirements. The unit isolates the antenna system from the transmitter when shooting trouble.

REQUIREMENTS

(1) Dissipates black-level power of 3 kw.
(2) Accurately terminates output of transmitter with no reflection.

PRINCIPLE - The principle of the R-F Load is illustrated in Figure 7-10. A small resistance R_1 can be inserted at section *A*. Section *B* should then be terminated for a surge impedance of $Z_0 - R_1$, which results in a smaller diameter. The process is continued until the required surge impedance is zero. This is merely a means of using a resistor of finite size when an infinitesimally small resistor would otherwise be needed for proper termination, since this is, practically, not feasible. The shape of the outer conductor, theoretically, follows an exponential curve, but a straight line is close enough an approximation for practical cases.

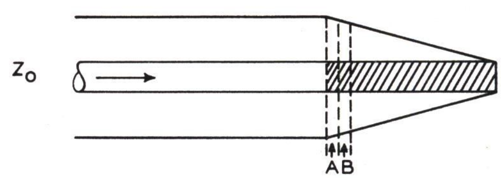


Figure 7-10 - Principle of R-F Load

The resistor is cooled by immersing it in a light grade of oil. With the unit in vertical position, the oil flows by convection to the top of the tank, where it is cooled by tap water while in use. Power is measured by measuring the voltage across the resistor, using a crystal detector for rectification.

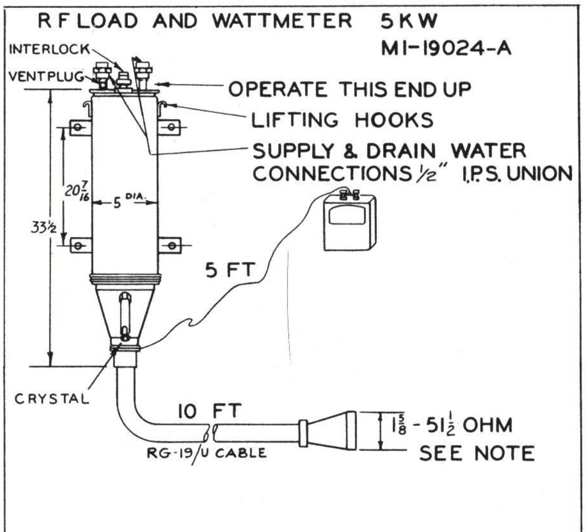
CONSTRUCTION - The load consists of a tank 5 inches in diameter and 33 1/2 inches overall in height. Connections are made to the output of the transmitter by 10-foot lengths of flexible RG-19/U cable. The unit terminates a 51.5-ohm line and, if used with the 75-ohm vestigial sideband filter, requires a quarter-wave transformer for conversion. See Figure 7-11.

DIPLEXER

PURPOSE - The diplexer permits the use of the same antenna for visual and aural transmission.

REQUIREMENTS

(1) Low cross-talk.
(2) VSWR of 1.1, or better, over the band.
(3) Minimum power absorption.



NAME	RF LOAD & WATTMETER 5 KW
MI	19024-A
FREQUENCY MC	44-216
WEIGHT LBS.	46
RF INPUT	1⅝ 51½ Ω
RF OUTPUT	
NON RF CONNECTIONS	TAP WATER 1 GALLON PER MINUTE
TYPE OF MOUNTING	VERTICAL SURFACE

Figure 7-11 - R-F Load and Wattmeter Construction

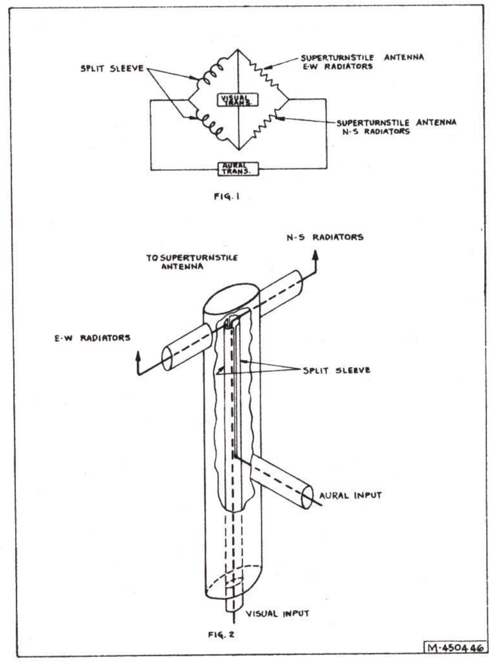


Figure 7-12 - Diplexer Schematic Diagram

PRINCIPLE - Because of the turnstiling principle, which will be discussed under the heading ANTENNAS, the antenna can be considered as two separate loads - a N-S radiator and an E-W radiator - which do not interact (see Figure 7-12). The diplexer is a bridge circuit, as shown in diagram 1 of Figure 7-12.

The visual transmitter output is single-ended and must be converted to a double-ended output. This is done with another balun unit, applying the same principle as discussed previously.

The use of a combination of sideband filter and diplexer is illustrated in Figure 7-13. The energy from the picture transmitter goes through the vestigial sideband filter, where the unwanted part of the lower sideband is suppressed. The energy to be transmitted then passes through the diplexer, where the sound energy joins in. The combined television signal (visual and aural energy) is then fed to the antenna over twin transmission lines, of which one is made one-quarter wavelength longer than the other to provide proper quadrature-phasing in the antenna. This last point is discussed in a later paragraph concerning the turnstiling principle.

CONSTRUCTION - The construction of the diplexer is apparent from Figure 7-14 and is not further described here.

PERFORMANCE

(1) No cross-talk has ever been encountered in the many checks that have been made.
(2) The VSWR is 1.1, and usually better, over the band.
(3) The power absorbed is a fraction of a decibel.

ANTENNA

REQUIREMENTS (ELECTRICAL)

(1) Horizontal polarization.
(2) Operation in 54-88 mc and 174-216 mc bands.
(3) Low VSWR over channel.
(4) Gain sufficient to provide good coverage.
(5) Pattern to be circular.

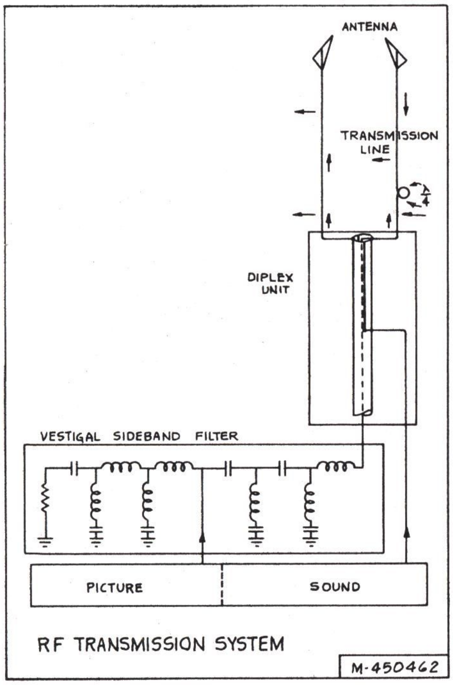
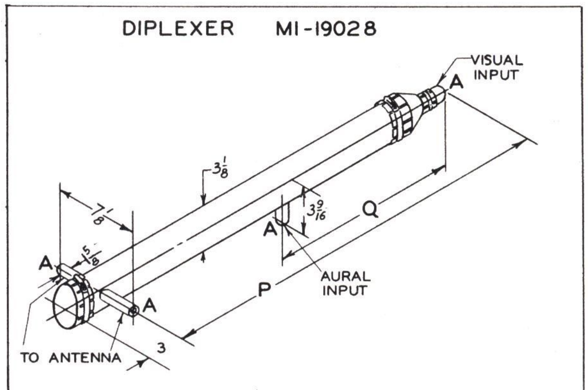


Figure 7-13 - R-F Transmission System



CHANNEL	P	Q	CHANNEL	P	Q
I	133 15/16	68 7/8	VIII	36 5/16	20 1/16
II	107 7/16	55 5/8	IX	35 5/16	19 9/16
III	97 9/16	50 11/16	X	34 5/16	19 1/16
IV	89 7/16	46 5/8	XI	33 9/16	18 11/16
V	78 9/16	41 3/16	XII	32 9/16	18 3/16
VI	73 5/16	38 9/16	XIII	31 13/16	17 13/16
VII	37 9/16	20 11/16			

NAME	DIPLEXER
MI	19028
FREQUENCY MC	54–216
WEIGHT LBS.	12 TO 30
RF INPUT AND OUTPUT	1 5/8-51 1/2 Ω (SEE K-8889742)
TYPE OF MOUNTING	HORIZONTAL ALONG TRANSMISSION LINE (CAN BE SUSPENDED ABOVE VESTIGIAL SIDE-BAND FILTER OR TRANSMITTER.)
MAXIMUM POWER	5 KW
RF EFFICIENCY	99%

Figure 7-14 - Diplexer Construction

(6) Ability to handle visual and aural power of transmitter, and additional FM transmitter in some cases.
(7) Must lend itself to transmission of visual and aural energy from the same antenna.
(8) Transmission of FM from the same antenna is also desirable.

REQUIREMENTS (MECHANICAL)

(1) Low wind resistance.
(2) Mechanically rugged.
(3) Sleet melting provision.
(4) Minimum number of end seals.
(5) Not to be vulnerable to lightning.
(6) Easily erected.

PRINCIPLE

(1) For low VSWR response over the band (1.1 or better), use is made of the second general principle, previously discussed under the heading BANDWIDTH, of combining a parallel-resonant with a series-resonant circuit. Such a combination circuit, using lumped parameters, was shown in Figure 7-3, together with its reactance-frequency characteristic curve. The distributed-parameter equivalent, which forms an antenna, is shown in Figure 7-15a. Its reactance-frequency curve is given in Figure 7-15b.

Addition of a second stub to the arrangement of Figure 7-15a provides a second ground point and adds rigidity; see Figure 7-15c.

In general, radiators with large diameters tend to have a more constant impedance over a given band since the ratio X_L/R, and hence the "Q", is smaller. Since a large diameter is not suitable for mechanical reasons, the same advantages are obtained by using a large flat sheet. This sheet can be visualized as a series of dipoles, each carrying a current proportional to the current distributed along the two stubs. See Figure 7-15d.

By notching-in the sides, the current in the upper and lower edges of the radiator, also called "batwing", is increased, which flattens the vertical pattern and increases the gain. One radiator has the same gain as two dipoles spaced one-half wavelength apart. See Figure 7-15e.

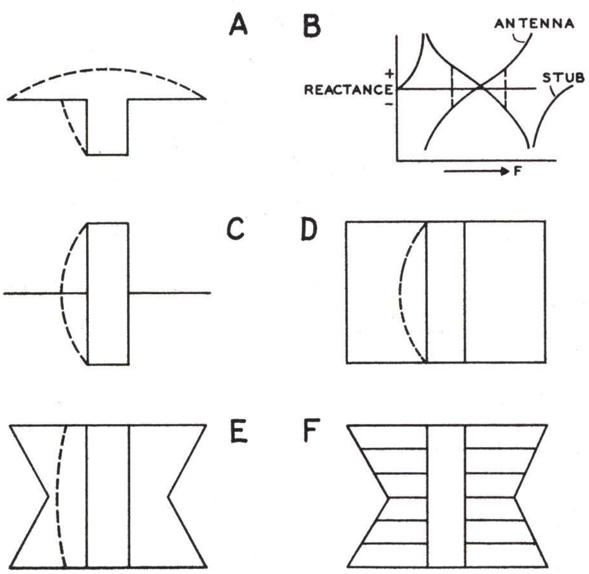


Figure 7-15 - Development of TV Antenna

By experimentally determining the minimum number of rods that can be used instead of a solid sheet, wind resistance is considerably reduced. See Figure 7-15f.

(2) *The Turnstiling Principle* - We now have a dipole with wide-band characteristics. To obtain a circular pattern, turnstiling is applied.

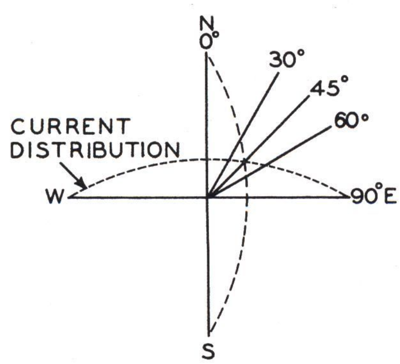


Figure 7-16 - Turnstiling Principle (Field Magnitude is Proportional to the Angle Between Direction of Radiator and Direction of Observation)

A circular radiation pattern can be obtained from cross dipoles arranged in the shape of a turnstile as follows (see Figure 7-16):

Angular Bearing	0	30°	45°	60°	90°
Field from N-S Radiator	0	0.5	0.707	0.866	1.0
Field from E-W Radiator	1.0	0.866	0.707	0.5	0
Vector Addition	1.0	1.0	1.0	1.0	1.0

To achieve this effect, the phase difference between the currents in the N-S and E-W radiators must be 90°, which is accomplished by making one of the lines 90 degrees (or one-quarter wavelength) longer than the other.

(3) *Stacking Sets of Radiators to Increase Gain* - This principle (see Figure 7-17) is an old one and has been used for years in communications antennas. If the currents in radiators *A*, *B*, *C* have the same phase (same number of wavelengths from the source) and if distances *AP*, *BP*, and *CP* are substantially alike, the field at *P* will be greater than that produced by a single radiator. Similarly, sets of batwing radiators are stacked to increase the gain. The length of the feed-line for each set, back to junction point, is kept the same. The centers of the successive radiators are spaced one wavelength apart.

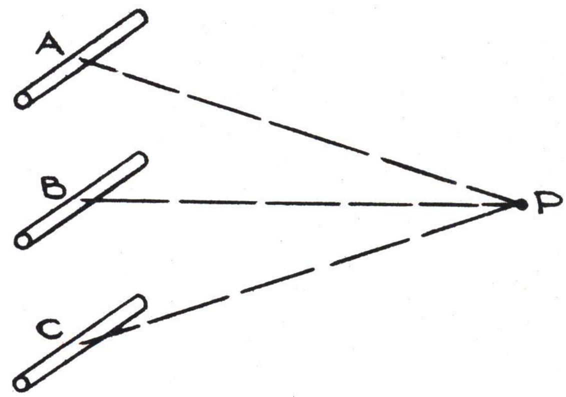


Figure 7-17 - Stacking of Antenna Radiators

CONSTRUCTION - The sets of crossed super-turnstile radiators are mounted on flag poles. The number of radiators that can be stacked is limited by the flag-pole taper and mechanical requirements.

The following types have been made:

FREQ. (MC)	STANDARD	SPECIAL
54-66 66-88 174-216	3-bay 3-bay 6-bay	4-bay, 5-bay

In the 3-bay antenna, each radiator has a 154.5-ohm impedance from the feed point at the center to ground. For three radiators in parallel, this becomes 51.5 ohms, which is the surge impedance of the main transmission line. Each branch line has an impedance of 154.5 ohms. For other types, transformers are used.

PERFORMANCE (ELECTRICAL)

(1) The antenna has extremely wide bandwidth. One set of radiators covers the 54-66 mc band -22%; another the 66-88 mc band -33%; and a third set covers the 174-216 mc band -25%. The pole-to-radiator spacing is varied slightly for each channel by means of pads or adjustments. An SWR of 1.1, or better, can always be achieved.

(2) The gain approaches the ideal that can be achieved and is 1.2 times the number of sections. This gain is obtained by measuring the vertical field pattern and taking into account losses in the radiators and feed system.

An exact tabulation of gain is shown:

	3-BAY		3-BAY			6-BAY						
TV Channel	2	3	4	5	6	7	8	9	10	11	12	13
Approximate Gain	3.3	3.7	3.3	3.8	4.1	6.4	6.6	6.7	6.8	6.9	7.0	7.1

(3) Theoretically the pattern is circular, but actually it departs from this slightly because the super-turnstile radiator is not a point source. This produces a square circle which, under ideal conditions, deviates by less than ±0.5 db. At no frequency within the specified TV channel will the pattern deviate by more than ±1.5 db.

(4) The antenna will handle a power of 20 kw, which is limited by the feed lines. The actual power for a 5-kw TV transmitter is 3 kw of visual power (black level) and 2 1/2 kw of aural power. This power is multiplied by the VSWR to allow for local heating at the current peaks. For TV, this is only 1.1. Hence, the total TV power is 6 kw. When triplexing is used, FM power is then limited to 14 kw divided by the maximum VSWR that may occur in the feed lines. This amounts to 10 kw for the 66-88 mc antenna, and 3 kw for the 54-66 mc antenna.

(5) By using the turnstiling principle and the bridge circuit of the diplexer, both visual and aural power can be transmitted over the same antenna. In addition, a triplexer enables the antenna, because of its response in the 88-108 mc band, also to be used to radiate FM power.

PERFORMANCE (MECHANICAL)

(1) Low wind resistance is achieved as a result of the open super-turnstile radiators.

(2) Ruggedness is achieved by:

(a) The inherent stiffness of triangular structures. Both top and bottom are firmly grounded and no weight is supported on insulators.

(b) The pole is made from Bessemer seamless steel tubing which has a U.T.S. of 60,000, and has shown as much as 70,000, 80,000, and even 120,000 on actual test. Since the material is stressed only to 20,000 lbs./square-inch, a high safety factor is obtained.

(c) Calculating 20 lbs. per square-foot of wind loading on rounds, a wind velocity of 95 miles per hour is required to stress the material to 20,000 lbs. per square-inch without ice. With 1/2 inch of radial ice, a velocity of 85 miles per hour is required to reach this same stress value.

(d) All brackets and radiator clamps are bonderized and zinc plated.

(3) De-icing is done for electrical reasons only, and not to reduce wind loading. Hence, only the section adjustment to the main pole is de-iced, which is the only portion affected by ice.

Heaters are used as follows:

ANTENNA TYPE	WATTS PER RADIATOR	KILOWATTS PER BAY
54-66	750	3
66-88	500	2
174-216	250	1

(4) Minimum end-seals are needed for feeding this antenna.

NUMBER PER BAY	ANTENNA TYPE
2	54-66 and 66-88
4	174-216
8	Dipole Construction

TOWER DESIGN - RCA has published the projected area of the antenna as well as other pertinent dimensions. From this information the tower manufacturer can design his tower. A standard specification is now being considered by RMA committees, which will put all tower designs on the same basis.

The tower should be designed to take the standard guide flange and pole sockets provided (see Figure 7-18).

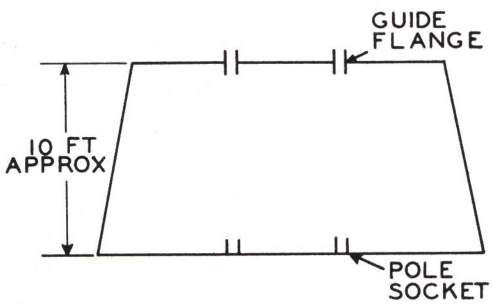


Figure 7-18 - Antenna Tower Layout

INSTALLATION

SHIPMENT - The pole can be shipped broken down as follows:

(3) Electrical leakage tests
(4) VSWR check over the band, with panoramic sweep equipment.

The RCA Service Co. has experienced men and suitable equipment, and is prepared to render this service at a reasonable cost. These tests should be made, whether the antenna is assembled in Camden or in the field. Simple corrections become extremely complex to make after the antenna is erected.

ERECTION

IN ONE PIECE - When the antenna is to be erected in one piece, the pole should be welded before assembly. Quite a number of installations have been successfully made in this way.

PARTIAL DISASSEMBLY AND REASSEMBLY - The disassembly should be done by the riggers who will reassemble the antenna. Feed lines should be carefully removed and kept in the original position. The pole need not be welded if this is done, but can be caulked after erection.

RIGGERS - It is most economical to use the same riggers who are erecting the tower. The same gin poles, donkey engines, etc., can be used.

	ANTENNA	NUMBER OF POLE SECTIONS	LENGTHS - FT. AND INCHES		
3-bay	54-66	3	17'6"	23'0"	24'0"*
3-bay	66-88	2	21'6"	30'0"*	
4-bay	66-88	2	36'2"	32'6"	
5-bay	66-88	3	28'8"	31'0"	29'0"
6-bay	174-216	2	26'8"	22'1" */**	

* *For Pylon mounting, the sections listed on the right are 3 to 6 ft. shorter.*

** *On most installations to date, this antenna, because of its greater number of parts, higher frequency, and more critical assembly, has been assembled in Camden by workmen and engineers familiar with this work. The antenna has then been shipped to the customer in one piece.*

ASSEMBLY - If the antenna is assembled on the customer's premises, it should be assembled on the ground in a horizontal position, with the pole resting on saw horses. This assembly should be done under engineering supervision. The feed system should be put on the antenna. The bending tool provided should be used. Kinks and flats on the line must be avoided.

TEST ON GROUND - After assembly, the RCA Service Co. should be requested to make the following checks:

(1) Gas leaks
(2) D-C resistance

This requires close scheduling.

PAINTING - The pole and radiators are shipped with one coat of red lead only, for protection in transit and during erection. They should be painted with CAA colors after erection. All portions, except the end seals, can be painted.

SPECIAL ANTENNAS

4-BAY AND 5-BAY - These antennas have been built for the 66-38 mc band. None have been built for the 54-66 mc band, although there is no technical reason to prevent it. It is not feasible to carry flag-pole construction to greater gains, because the pole taper causes a wider spacing between the lower radiators, resulting in a different impedance than for the upper sections.

SUPER-GAIN ANTENNAS - These antennas will take the form of a tower type. One type would consist of dipoles mounted on the four faces of a tower one-half wavelength square. Such antennas are used for three reasons:

(1) *Higher Gain* - The allocation scheme of FCC is based on 50 kw radiated power. A 5-kw transmitter, with a standard 3-bay or 6-bay antenna and nominal line loss, will radiate about 15 kw in the 54-88 band, and 25 to 30 kw in the 174-216 band.

Super-gain antennas will permit gains of 10 and 12, so that 50 kw radiated power can be achieved.

(2) *Stacked Antenna Systems* - If one site is desirable for several television stations, the lower antenna can be a tower type and the upper a standard type. Propositions have been worked up for three television stations with additional FM Pylons. Since receiving antennas are directive and generally aimed at a central cluster of stations, it is highly advisable to be in this central cluster. The use of the stacked antenna makes this possible.

(3) *Directional Antennas* - Radiators can be left off on one or two faces of the tower, to produce a directional pattern. Directional patterns are not recommended as a rule, since the total area covered is less. See Figure 7-19.

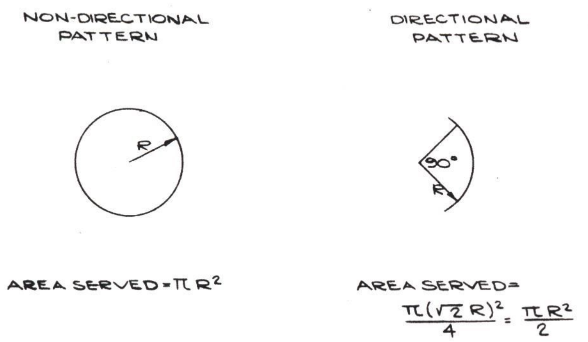


Figure 7-19 - Antenna Radiation Patterns - With the directional pattern shown, the area served is one-half the area covered with the circular pattern. Also, four times the power is concentrated in a same area. Hence, the field strength is doubled and the radius is extended by $\sqrt{2}R$ (as a general approximation, the service radius varies as the fourth root of the power).

In some cases, of course, where mountains behind the station cause serious ghosts or where protection to other stations is necessary, directional antennas must be used.

COMBINATION ANTENNAS

a. COMBINATION WITH FM BY USE OF PYLON ANTENNA

A 2- or 4-section Pylon underneath a TV antenna can be placed below any 3- or 4-bay antenna in the 54-88 band, or a 6-bay antenna in the 174-216 band.

Pylons have a gain of 1.5 per section midband and will take up to 50 kw of FM. They are 20 inches in diameter and 14 feet high. The FM feed system is inside. The TV system is mounted on the back of the pylon, opposite the slot. All FM-pylon and TV-antenna combinations have been checked for structural soundness by independent consultants.

b. COMBINATION WITH FM BY USE OF TRIPLEXING

Purpose - To use TV antennas for FM radiation.

Requirements

(1) Must keep FM out of TV and vice versa.
(2) Must not disturb VSWR of either service.
(3) Must have low insertion loss.

Principle - The TV and FM energies are kept flowing in their proper paths by suitable notch filters, as shown in Figure 7-20.

Construction - The external dimensions are the same as those of the 54-88 mc diplexer.

Performance - Installations made at stations WNBW, WEWS, WLWT, are all working satisfactorily.

Power Limitations - Because of limitations in the feed system of the super-turnstile antenna discussed previously, FM power is limited to 10 kw for the 66-88 mc antenna and 3 kw for the 54-66 antenna.

c. USE OF TV SUPER-TURNSTILE FOR FM ONLY -

This implies that the TV installation will be made at a later date.

Principle - See Figure 7-21.

d. COMBINATION WITH AM

Purpose - Use of AM tower for TV antenna support.

Principle - TV line must be isolated from ground at AM frequency.

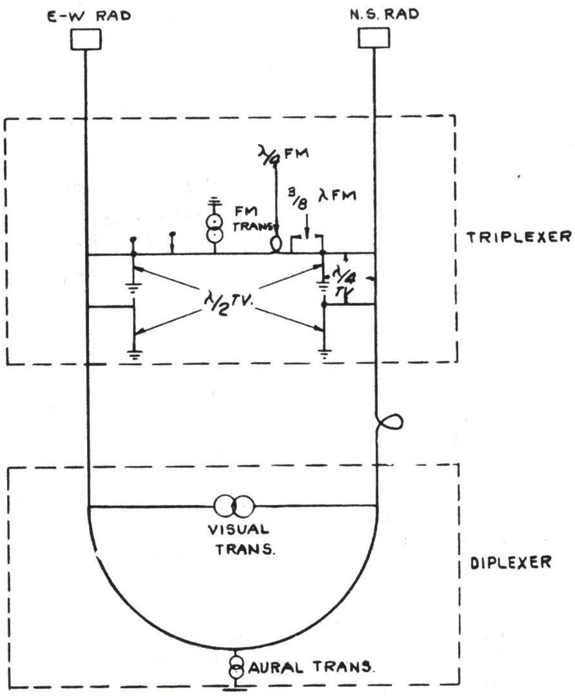


Figure 7-20 - Principle of Triplexing

As shown in Figure 7-22a, the tower acts as the outer conductor of a balun. The capacitance at the end *A* loads the balun to resonance if the tower is not high enough to furnish one-quarter wavelength at the AM frequency.

Referring to Figure 7-22b, a balun of wires is constructed around the TV line approaching the AM tower for a distance of one-quarter wavelength, or equivalent.

TRANSMISSION LINE

PRINCIPLE - Without insulators, the surge impedance is

$$Z_o = 138 \log \frac{D\ (outer)}{d\ (inner)} .$$

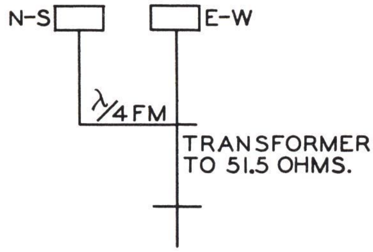


Figure 7-21 - TV Superturnstile Antenna

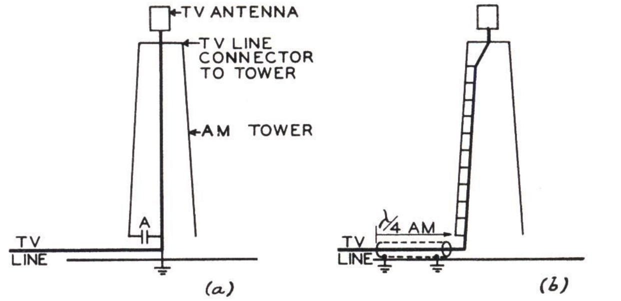


Figure 7-22 - Use of AM Tower for TV Antenna

In practice, insulators are always required. The line must then be treated as made up of recurrent T-sections, with each insulator considered as a lumped capacity. See Figure 7-23.

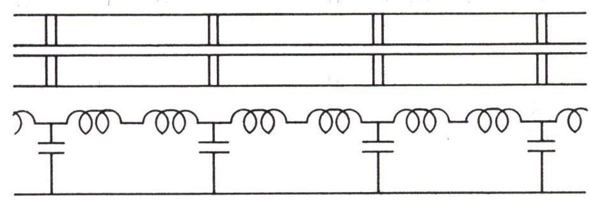


Figure 7-23 - Transmission Line Principle

This brings about two additional considerations:

(1) The line must always be cut half-way between insulators, to avoid discontinuities.

(2) The line is really a filter and has a cut-off frequency. On standard RMA line, the cut-off point is above 216 mc, due to a proper choice of insulator capacity and spacing.

RMA SIZES - Standard sizes are 7/8, 1-5/8, 3-1/8 and 6-1/8 inches. Of these, the 1-5/8- and 3-1/8-inch sizes are the most widely used for 5-kw TV installations.

SURGE IMPEDANCE - The value is 51.5 ohms for all sizes. The primary consideration in this choice was the I^2R loss, with a slight compromise on attenuation. The odd value of 51.5 ohms was chosen because this is the actual impedance of solid-dielectric line. Hence, the two types of line can be used in the same run.

POWER RATING - This is one-half the power required to raise the temperature of the outer conductor 40° C.

SIZE (IN.)	50 MC	100 MC	200 MC
7/8	4.5 kw	3 kw	2 kw
1 5/8	16	10	7
3 1/8	64	42	27
6 1/8	235	166	118

LOSS - Loss takes into account copper loss, insulation loss, and some derating due to connections. The average power transmitted at 100 mc over a 500-foot run of line is 75% for the 1-5/8-inch line and 85% for the 3-1/8-inch line. See published curves in the RCA equipment specification.

GAS - Dehydrated air, obtained from a commercial dehydrator, is probably best. Only a *small* positive pressure is needed; 5 lbs. is adequate.

CONSTRUCTION - See Figure 7-24. The primary purpose of this construction is two-fold:

(1) To prevent electrical discontinuities in the line.
(2) To make the installation as nearly foolproof as possible.

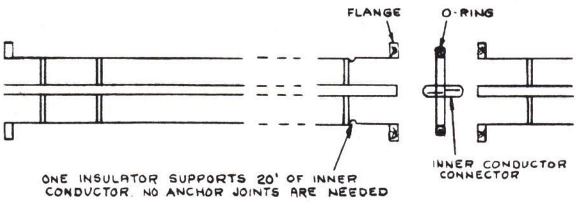


Figure 7-24 - Transmission Line Construction

No soldering or brazing is needed in the field. If a length other than 20 feet is needed, the line is cut and a flange adapter is used, which requires no brazing. Flange joints are pulled up tight and require no "feel".

FITTINGS - Fittings must be designed to prevent electrical discontinuities. This means that diameters must remain the same and insulators must continue at the same spacing. Elbows must have a wide sweep. See Figure 7-25.

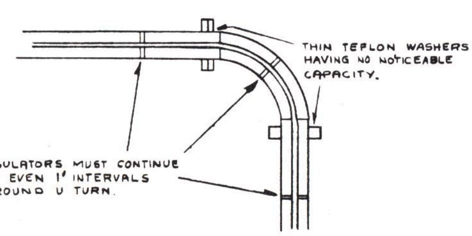


Figure 7-25 - Transmission Line Elbow Fitting

TELEVISION STANDARDS - While lines intended for TV and FM have the same approximate dimensional standards and external appearance, the surge impedance limits on TV line are tighter because the reflection problem is highly important in television. In ordering lines, be sure to specify it for TV standards, or better yet, order it through RCA.

CUTTING POINTS OTHER THAN HALF-WAY BETWEEN INSULATORS - If this is absolutely necessary, a point should be chosen further back, where the line can be cut half-way between insulators. The odd balance is then filled out with a line containing no insulators and having a diameter that will give a surge impedance of 51.5 ohms.

EXTRA QUARTER-WAVE FOR DIPLEXING - The equipment specifications (AS-5979) show several methods of introducing this at the diplexer. It also gives a table, for each channel, of the difference that should exist, taking into account the actual velocity of propagation along the line.

ATTACHING LINE TO TOWER

ELECTRICAL REQUIREMENTS - Both lines should be as identical as possible all the way down the tower. Flanges and elbows should be located in the same places from the tower top to the diplexer in the station, where the extra quarter-wave is inserted. This is because each elbow can insert a slight mismatch. If the two lines are exactly alike as to mismatch, the latter is balanced out by the extra quarter-wave section, which inverts the reactance.

MECHANICAL REQUIREMENTS - The primary requirement is to provide allowance for expansion. The following should be noted.

(1) Expansion of the inner conductor is made possible by the sliding of the spring-loaded inner-conductor connector.

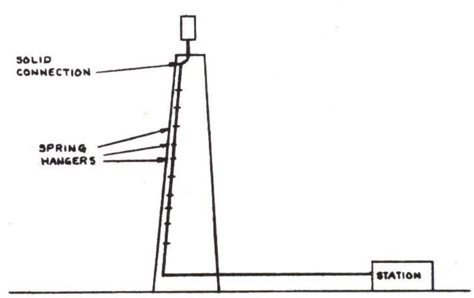


Figure 7-26 - Transmission Line Installation Layout

(2) Expansion of the outer conductor is permitted by spring hangers. The line is connected solidly at the top of the tower; and then

it is connected to the tower every 10 feet (see Figure 7-26). These hangers are pre-loaded in accordance with the temperature conditions at the time of erection. Under ordinary climatic conditions, expansions of 1 inch in 100 feet will occur, and this will be accommodated by the hangers. An elbow at the bottom of the tower should be arranged to take this movement.

If the tower is more than 500 feet high, the arrangement can follow the layout shown in Figure 7-27.

CHECKING LAYOUTS - Transmission line layouts will be checked by RCA for accuracy and completeness, if submitted.

NOTE - *Any pains taken in establishing a good transmission line and antenna installation pays enormous dividends. Here, if anywhere, a slight effort in time will prevent expensive and lengthy delays at a later date.*

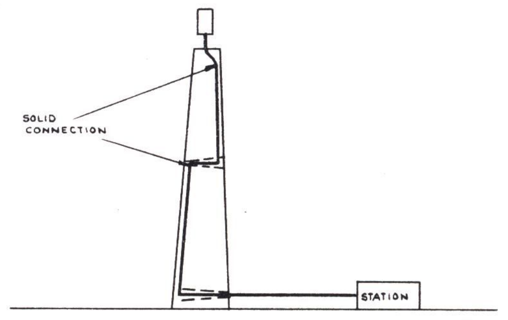
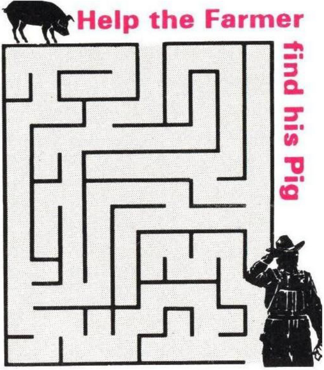


Figure 7-27 - Transmission Line Installation Layout

Help the Farmer find his Pig



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Word Find

Bacon, Barn, Corn, Farm, Grain, Ham, Hog, Lean, Pen, Piglet, Pigs, Pork, Oink, Sow

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