Section 6

STUDIO FACILITIES

Part 1

PLANNING AM/FM STUDIO FACILITIES

NAB ENGINEERING DEPARTMENT [*]

GENERAL PLANNING CONSIDERATIONS

The early planning of a radio station usually involves consideration of the market to be served, site selection, transmitter power, tower height, station policies, personnel, the extent of programming, the hours of operation, and available capital. In this part we confine ourselves mainly to the selection and arrangement of equipment to achieve the desired results. First and foremost of the decisions to be reached is whether the studio and transmitter are to be combined under one roof or to be in separate locations.

In the past few years there has been a trend toward combined studio and transmitter facilities rather than separated facilities. More recently, however, there has again been a trend toward separated installations, with the transmitter operated by remote control from the studio where permissible.

It is generally agreed that wherever practical it is most economical to combine the studio and transmitter facilities. The initial equipment requirements are less, and more important is the fact that day-to-day operating expenses are lower. With the plant "all under one roof" there are savings in heating and air conditioning, building maintenance, and travel time, and in addition, less technical personnel is required. A "combined" operation, however, is not always practical. There are several important considerations:

1. Is the combined location the best spot for the transmitter site? (By that we mean is there sufficient room for installation of tower or towers and an adequate ground system? Furthermore, is it more advantageous from a standpoint of providing the desired coverage?)

2. Is the combined location convenient and accessible for station personnel and for clients? (A combined location is generally more practical in smaller cities, since an accessible and satisfactory location for both studio and transmitter can usually be obtained near the city limits.)

When a combined operation is not practical, the second most economical approach, where permissible, is to operate the transmitter by remote control from the studio. Then one can select a transmitter site that is most advantageous from a radiation and coverage standpoint, and the studio could logically be placed at its most convenient location. The building requirements at the transmitter can be the very minimum, requiring only space for the equipment, a small work area, and a small room-heating unit. The studio contains conventional equipment and a remote-control unit. This type of installation is one of the most desirable for larger cities.

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[*] Compiled from sources listed in this part.

Control Room

All control-room installations, large or small, are alike in many respects. The differences are mainly a matter of the number of microphones, turntables, tape recorders, and other program sources to be served. This, in turn, will dictate the type of consolette or control console that is most suitable. Beyond this, there are various arrangements of facilities to suit special conditions and personal tastes. For economic reasons, most stations locate the control console in front of the studio viewing window. They locate the turntables on either side of the operator's position at the console, a microphone over the console for control-room annuncing, and tape-recording equipment within easy reach of the operator.

House Monitoring

A house-monitoring system is an important function, and proper planning before construction begins will provide a much neater installation. Provisions should be made to carry audio to several locations throughout the building, the lobby area, offices, clients' room, etc. Besides normal program material, it provides a convenient closed-circuit system for auditions and special monitoring.

Ductwork

The careful planning and layout of trenches and ducts for wiring is essential to economical installation and efficient operation. Once the technical equipment has been accurately determined, it is then time to plan trench runs. These should provide for some measure of future expansion.

Studio Considerations

As we examine present-day operations, we find the studio receiving less consideration because fewer live programs are being originated. However, we have further discovered that neglect in the planning of the studio places a later handicap on the average operation, which could have been prevented with only a small additional expense and a little careful consideration at the time of construction. Hence in this article we present plans that provide for normal expansion without undue expense.

EQUIPMENT PLANNING *

The next most logical step after early plans have been completed is the careful and considered planning for the technical equipment. This goes hand in hand with the building design and construction. Equipment planning is the proper selection and layout of technical equipment to satisfy contemplated programming requirements.

We are going to cover three versatile plans for radio station equipment, which do not necessarily represent any existing stations but do illustrate several ways in which the very latest equipment can be arranged to perform efficiently with a minimum of capital and personnel.

Since programming requirements vary, we present three plans, which represent three specific categories of operation:

1. Plan *A* covers a typical "combined" studio-transmitter operation, with programming requirement of records and transcriptions, control-room announce, one studio, tape facilities, network, and remotes. This is a small station, requiring minimum investment.
2. Plan *B* also covers a "combined" operation but incorporates additional facilities to allow for an announce booth and other local program material. It is a typical community station of moderate size.

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* The following material was based on an article entitled, "Planning a Radio Station," contained in *RCA Broadcast News*, vol. 97, October, 1957.

3. Plan *C* covers a fairly large two-studio station with separate studio and transmitter locations but with optional remote operation of the transmitter. It is designed for large-city operation, providing a high degree of flexibility and facilities for extensive programming.

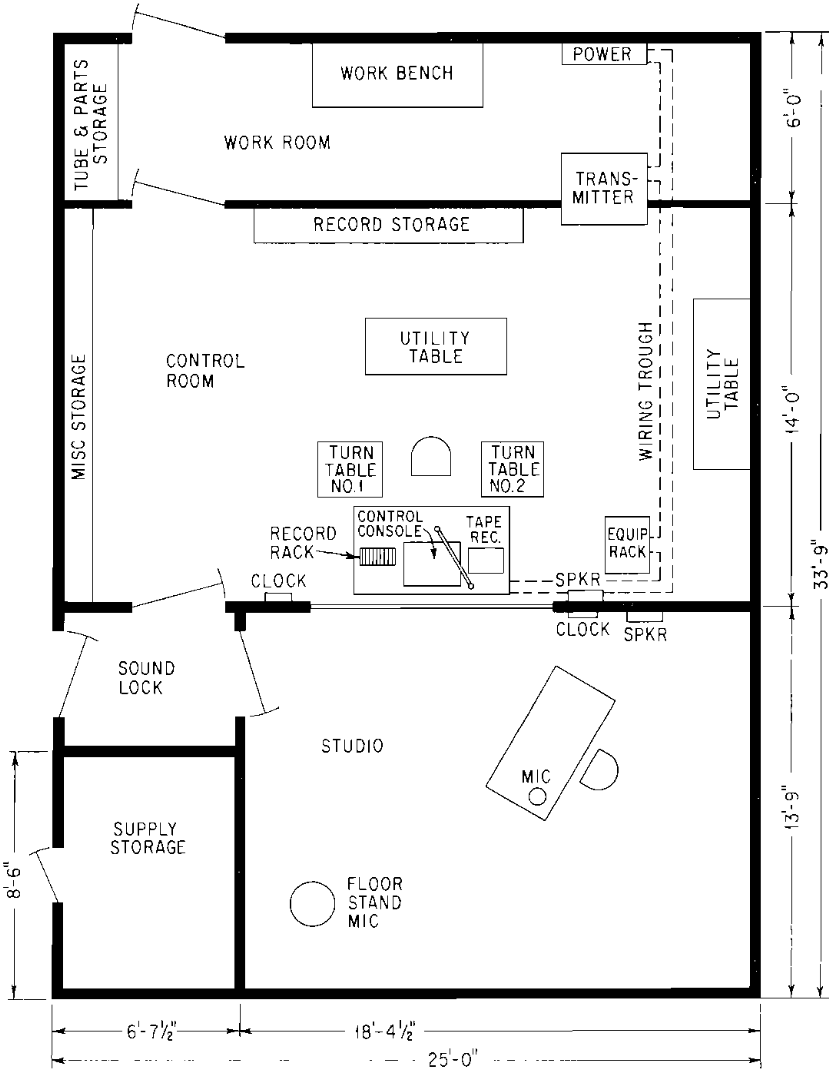


Fig. 1-1. Floor plan *A*: location of major equipment items. Observe the convenient location of the wiring through (dotted lines) for accessibility to the necessary equipment.

The three plans are considered adequate for the majority of cases, and each is so arranged that the plan can be modified to suit individual requirements. The choice of the equipment layout will depend to a large extent on factors which are already determined: type of programming, area to be served, station policies, and personnel.

Plan *A*

Plan *A* is a desirable layout for the small station that proposes to start operation at minimum investment. It includes the necessary technical equipment for handling the following programs: (1) announcements, (2) record and tape shows, (3) network, (4) remotes, and (5) local live originations such as interviews and newscasts.

It will be noted in Fig. 1-1 that the floor plan is separated into combined transmitter and control room, small studio, engineering workroom and parts storage, supply storage, and a sound lock.

The major items of equipment required to perform the programming operation are identified on the floor plan. A block diagram and rack layout (Figs. 1-3 and 1-4) show how the system is connected. An equipment list itemizes the requirements, including the miscellaneous small items necessary to complete the system.

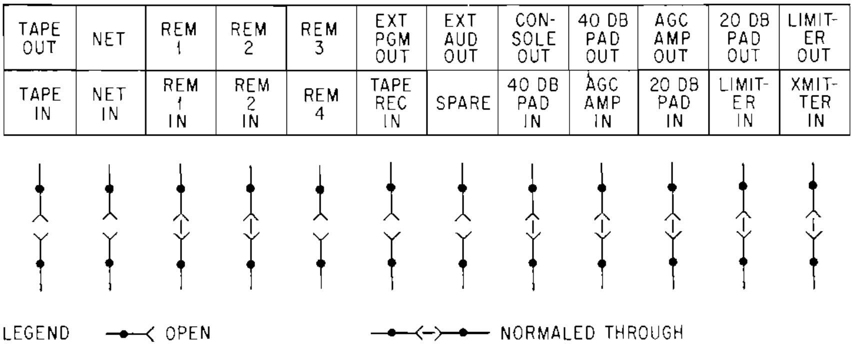
Table 1-1. Plan *A* Equipment List*

(Providing the facilities for handling records and transcriptions, announcements from the control room, one studio, tape facilities, network and remote programming.)

Quantity	*Control room*
1	Audio consolette with tubes
1	Dual headphone
1	Microphone
1	Microphone mounting
1	Microphone plug
1	Microphone receptacle
2	"On-air" lights
2	Three-speed turntables
2	Transcription tone arms
2	Pickup heads
2	Transcription equalizers or filters
1	Tape recorder
1	Input transformer for tape recorder
1	Output transformer for tape recorder
1	20-db 600-ohm fixed pad
1	Monitor speaker
1	Monitor-speaker housing
1	Speaker matching transformer
1	16-in. sessions clock
100 ft	Interconnecting cable No. 22 AWG shielded pair, with cotton-braided outer cover
	Studio
2	Ribbon microphones
1	Desk stand
1	Floor stand for microphone
3	Microphone plugs
3	Microphone receptacles
2	"On-air" lights
1	Studio monitor speaker
1	Monitor-speaker housing
1	Speaker matching transformer
Quantity	*Studio (Continued)*
1	16-in. clock
100 ft	Interconnecting cable No. 22 AWG shielded pair, with cotton-braided outer cover
	AM transmitter input and monitoring
1	Cabinet rack
1	AM frequency monitor
1	Modulation monitor
1	40-db 600-ohm fixed pad
1	Program amplifier with tubes
1	Mounting shelf for BA-25 amplifier
1	20-db 600-ohm fixed pad
1	Limiting amplifier with tubes
1	Mounting shelf for amplifier
1	Double-jack panel
1	Single-jack panel mat
400 ft	Interconnecting cable for audio rack wiring, No. 20 shielded pair, solid conductor
200 ft	Interconnecting cable for a-c and filament circuits, No. 18 shielded pair, stranded conductor
1	Terminal board mounting bracket
1	Terminal power strip
1	Terminal audio block
4	Audio patch cords, 2 ft in length
1	Switch and fuse panel
1	$3\frac{15}{32}$-in. blank panel
1	$1\frac{23}{32}$-in. blank panel
2	$8\frac{23}{32}$-in. blank panels
1	$5\frac{7}{32}$-in. blank panel

* Transmitter and antenna equipment are not listed here, since they are specified in accordance with power and pattern.

The choice of transmitter, of course, depends upon the power of the individual station. Regardless of power, all other items included in plan *A* remain the same.



TAPE OUT	NET	REM 1	REM 2	REM 3	EXT PGM OUT	EXT AUD OUT	CONSOLE OUT	40 DB PAD OUT	AGC AMP OUT	20 DB PAD OUT	LIMITER OUT
TAPE IN	NET IN	REM 1 IN	REM 2 IN	REM 4	TAPE REC IN	SPARE	40 DB PAD IN	AGC AMP IN	20 DB PAD IN	LIMITER IN	XMITTER IN

Fig. 1-2. Jack panel for plan *A*.

Plan *A* incorporates many features to permit operation with a minimum of personnel. It is designed for a single operator-announcer to work directly from the control room. The equipment location makes this practicable, since turntables, tape recorder, control console, and record rack are all within easy reach of the operator. The equipment rack is situated for convenient reading of the frequency and modulation monitor meters without leaving the operating position. Record-storage racks are easily accessible within the control room. Furthermore, the small utility storage rack and table, located directly behind the operating position, provides a handy place for keeping the daily program material ready for use.

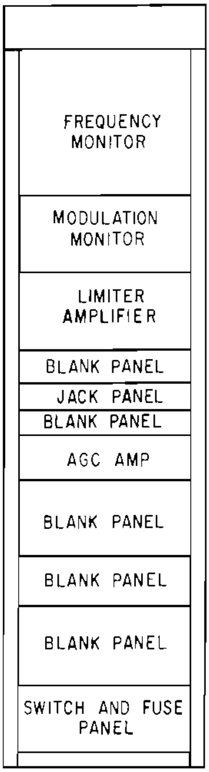


Fig. 1-3. Rack layout for plan *A* equipment. Note blank panels which allow for future expansion.

Entrance to the control room or the studio is via the common sound lock. The small engineering workroom with storage cabinet and workbench is sometimes neglected in planning but will prove its worth many times over. The wiring trough shown by dotted lines in Fig. 1-1 makes the wiring readily accessible for service or making additions to the system.

Technical Facilities of Plan A

The control console is the heart of the audio system. Because of its operational simplicity, it makes possible smooth and successful performance. This is owing to proper location of important controls. Both from a system standpoint and from the physical standpoint all controls are easily accessible to the operator. An examination of the block diagram (see Fig. 1-4) shows the functional location of the console in the system. Note the capabilities, especially the number of inputs and outputs.

Turntables are next in importance. They are three-speed units: 33⅓, 45, and 78 rpm. These utilize a simplified speed-changing mechanism, proved and reliable, driven by a hysteresis synchronous motor. The turntable starts very smoothly, which is so necessary with microgroove recordings.

A tape recorder is located on the table within easy reach of the operator. (This may be rack mounted, if desired.) It is a dual-track, two-speed (3¾ and 7½ ips) unit, driven

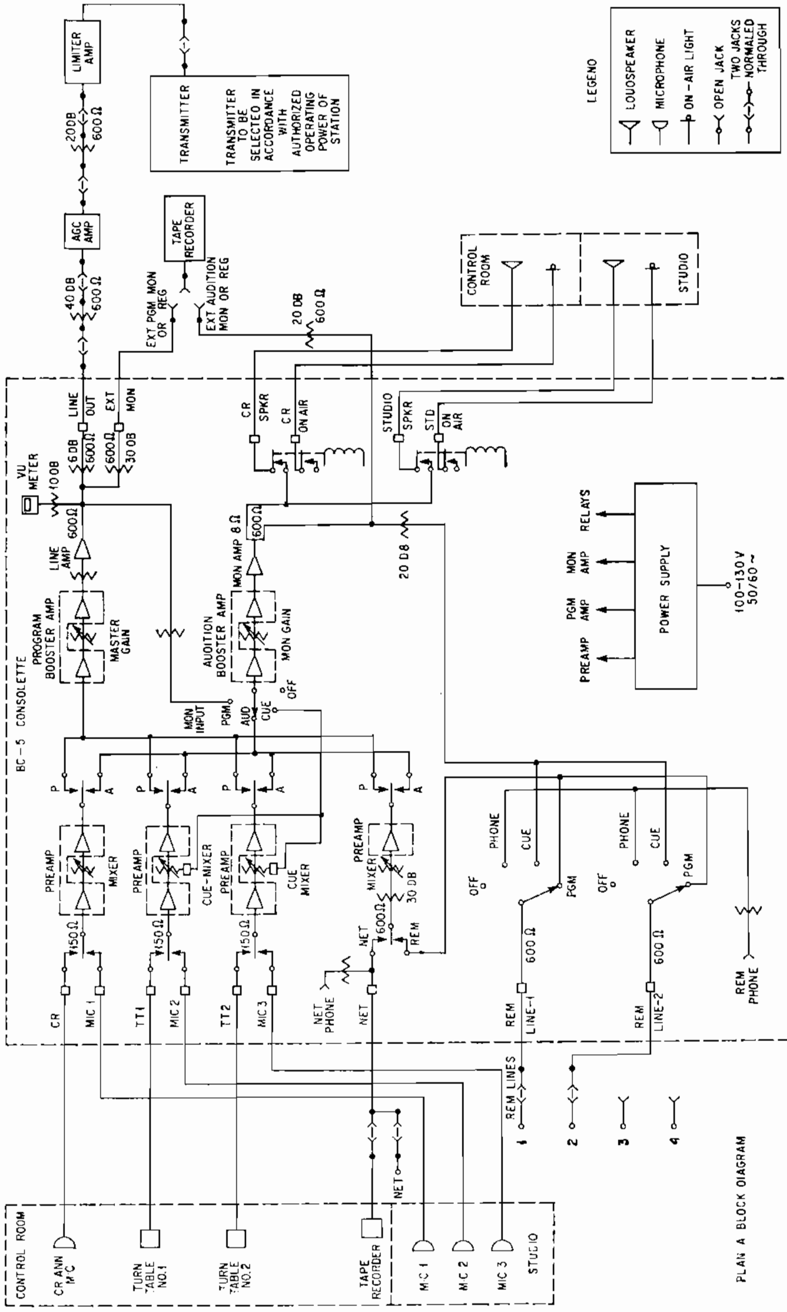


Fig. 1-4. System diagram for plan A.

direct by a synchronous motor. It utilizes the latest circuit techniques: transistor amplifiers and electrodynamic-tape tensioning and braking.

An automatic-gain-control amplifier and a limiting amplifier are located in the equipment rack. The functions of these two units in the system are related, and a description of their importance follows.

It is a well-known fact that station coverage, regardless of power, is definitely related to the ability to maintain the highest possible average level of modulation without distortion. The use of a limiting amplifier has been common for several years with reasonably good results; however, it has some limitations. In a limiting amplifier, the gain is constant up to a certain output level. Above this level, there is so much gain reduction that the output level will be maintained virtually constant. Thus, a limiting amplifier is effective only on high levels of program material.

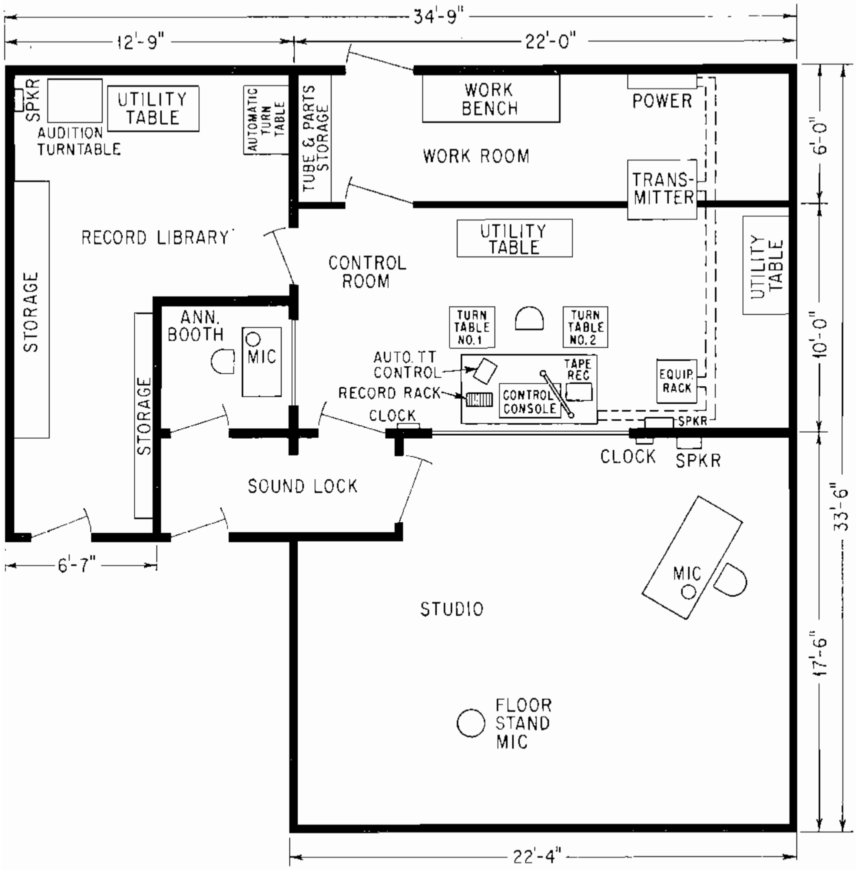


Fig. 1-5. Floor plan *B:* location of all major equipment items. Note the addition of an announce booth and a record library.

On the other hand, the automatic-gain-control amplifier (AGC) will serve to maintain a relatively constant output, much in the same manner that an operator might, by carefully and constantly "riding gain" on the program. The characteristics of the AGC amplifier and the limiting amplifier supplement each other ideally when connected in a system feeding a transmitter. This combination permits a higher average level of program material and prevents overmodulation on sudden program peaks, which effectively improves reception in fringe areas and extends coverage without increasing transmitter power.

Other major equipment items located in the equipment rack are the frequency and modulation monitors (required by the FCC) and a jack panel. The complete rack layout is shown in Fig. 1-3.

Plan *B*

Plan *B* typifies the most desirable arrangement for the community-type radio station. This plan fulfills all the requirements, from a space and facility point of view, for handling a very diversified program schedule. It incorporates technical features that make for an adequate yet economical operation. The following equipment list itemizes the equipment including the miscellaneous small items necessary to complete the system.

While plan *B* is identical in many respects with the plan *A* station, it includes larger and additional facilities (see Fig. 1-5). The major difference is a larger studio, the addition of an announce booth, and a record-library room. Additional

Table 1-2. Plan *B* Equipment List [*]

(Providing the facilities for handling records and transcriptions, announcements from the control room, one studio, announce booth, tape facilities, network and remote programming.)

Quantity	*Studio and announce booth*
2	Ribbon microphone
2	Desk stands
1	Floor stand
1	Uniaxial micropbone
4	Microphone receptacles
4	Microphone plugs
4	"On-air" lights
2	Studio monitor speakers
2	Monitor-speaker housings
2	Speaker matching transformers
2	16-in. clocks
150 ft	Interconnecting cable No. 22 AWG shielded pair, with cotton-braided outer cover
	AM transmitter input and monitoring
1	Cabinet rack
1	AM frequency monitor
1	Modulation monitor
1	40-db 600-ohm fixed pad
1	AGC program amplifier with tubes
1	Mounting shelf for amplifier
1	20-db 600-ohm fixed pad
1	Limiting amplifier with tubes
1	Mounting shelf for amplifier
1	Double-jack panel
1	Single-jack panel mat
400 ft	Interconnecting cable for audio rack wiring, No. 20 shielded pair, solid conductor
200 ft	Interconnecting cable for a-c and filament circuits, No. 18 shielded pair, stranded conductor
1	Terminal board mounting bracket
Quantity	*AM transmitter input and monitoring (Continued)*
1	Terminal power strip
1	Terminal audio block
4	Audio patch cords, 2 ft in length
1	Switch and fuse panel
1	Monitor amplifier with tubes for house monitoring system (speakers to be selected as required)
1	Plug-in transformer for amplifier
1	Mounting shelf for monitor amplifier
1	$3\frac{15}{32}$-in. blank panel
1	$1\frac{23}{32}$-in. blank panel
1	$5\frac{7}{32}$-in. blank panel
1	$8\frac{23}{32}$-in. blank panel
	Record library
1	Automatic turntable with remote control
1	Turntable
1	Transcription tone arm
2	Pickup heads
2	Transcription equalizers and filters
1	Utility amplifier
1	Monitor amplifier for audition
1	Plug-in transformer for amplifier
1	Selector switch for input of amplifier
1	Bridging pad for automatic-turntable audition
1	Monitor speaker for audition
1	Monitor-speaker housing
100 ft	Interconnecting cable No. 22 AWG shielded pair, with cotton-braided outer cover

[*] Transmitter and antenna equipment are not listed here, since they are specified in accordance with power and pattern.

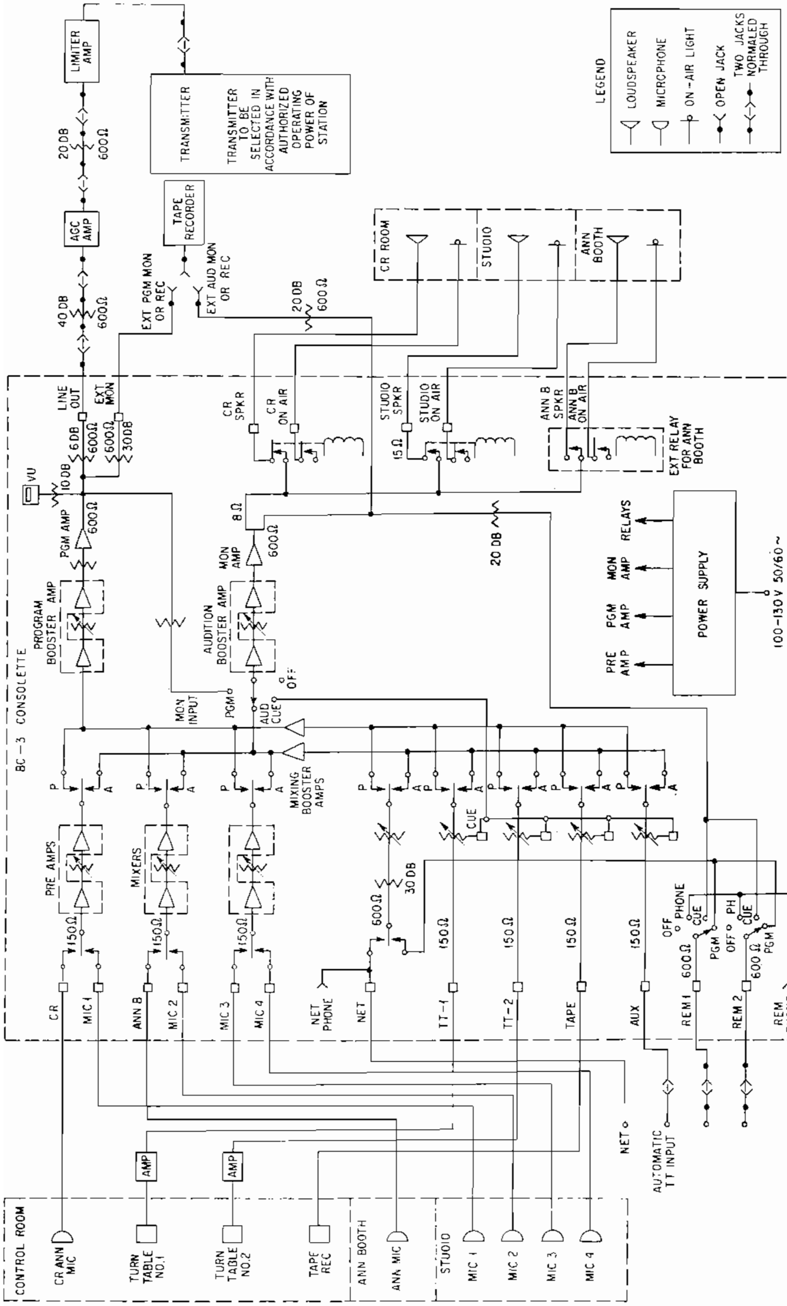
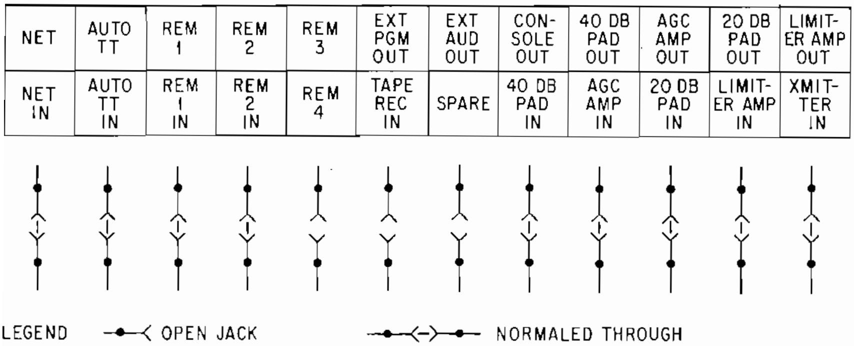


FIG. 1-6. System diagram for plan *B*.



NET	AUTO TT	REM 1	REM 2	REM 3	EXT PGM OUT	EXT AUD OUT	CONSOLE OUT	40 DB PAD OUT	AGC AMP OUT	20 DB PAD OUT	LIMITER AMP OUT
NET IN	AUTO TT IN	REM 1 IN	REM 2 IN	REM 4	TAPE REC IN	SPARE	40 DB PAD IN	AGC AMP IN	20 DB PAD IN	LIMITER AMP IN	XMITTER IN

Fig. 1-7. Jack panel for plan *B*.

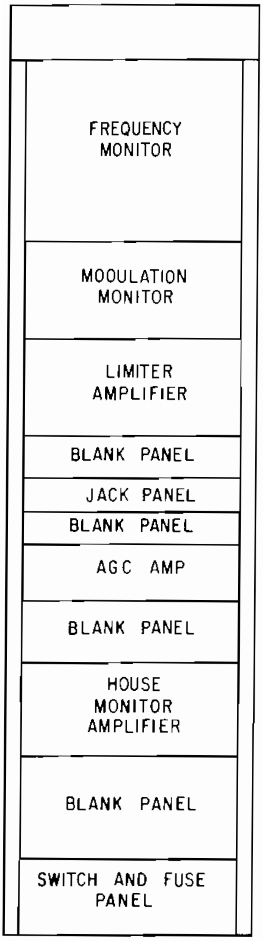


Fig. 1-8. Rack layout for plan *B* equipment.

equipment consists of an automatic turntable, another microphone, a monitor speaker, and associated items.

Now programming can be expanded to include the origination of a fairly substantial live studio show. Another important aspect of this plan is that with the announce booth serving as another point of origination, it becomes very practical to record announcements and other program material while on the air.

Again we have utilized a common sound lock, in the interest of economy, with the announce booth, studio, and control room all accessible from this area. The separation of the record library from the point of program origination makes it possible, with the facilities provided, to carry on auditioning of records, building of shows, cataloguing, filing, etc., without interruption during the program day.

It will be noted that the automatic turntable is located in the record library but controlled remotely from the operator's desk. This is convenient and further isolates the unit from the control room, so that any noise created while it goes through the change cycle will not go out on the air when the control-room announce microphone is open.

Technical Facilities of Plan B

The control console offers the additional system and operational functions required for Plan *B*. It retains, however, the operational simplicity of the console employed in plan *A*. As a matter of fact, it is simply an expanded version of plan *A*, just as plan *B* is essentially an expansion of plan *A*. An examination of the block diagram, Fig. 1-6, verifies this, showing the function of the consolette in this system.

The jack panel for plan *B* is shown in Fig. 1-7, and the rack layout in Fig. 1-8.

Three turntables are specified in the equipment list for plan *B*. The additional turntable, along with some accessory equipment, makes up a small system for auditioning records. Figure 1-9 gives the details as to how this system goes together.

A first step toward automatic, or unattended, programming is provided by the automatic turntable. It can be used at some later time as one of the building blocks in a complete, unattended programming system. The automatic turntable, in conjunction with a tape recorder, can be utilized at the present time for more effective programming. For example, taped commercials and announcements can be pre-recorded at any convenient time. Then the desired records are loaded into the automatic turntable. This, in conjunction with a cue sheet, will enable an operator to select and direct, simply and easily, the function of the units. Plans for unattended operation will, by necessity, require some changes in programming concept. A transition will be required from the old way to the new, and all stations will not find unattended programming operation applicable in the same way. Here, however, is the opportunity to gain experience and guidance for future planning.

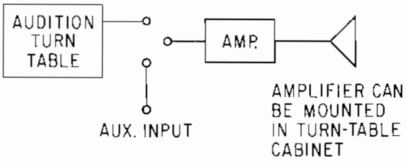


Fig. 1-9. Block diagram of record-audition system.

An automatic-turntable system (block diagram, Fig. 1-10) serves to provide necessary information for planning.

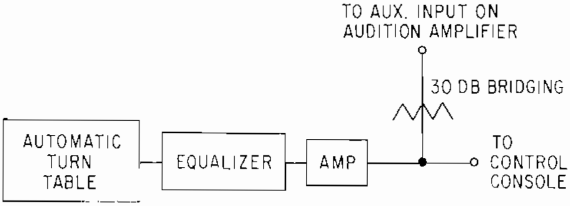


Fig. 1-10. Block diagram of automatic-turntable system.

Plan *C*

Plan *C* approaches the ultimate for the "larger" type of radio station as we know it today. From the floor plan (Fig. 1-11), it will be apparent that a high degree of flexibility is maintained, offering facilities for handling very extensive programming. Furthermore, it will be noted that plan *C* incorporates many of the same general considerations described for the other layouts but with several additions. There is also one significant deletion—the transmitter. In this plan we have assumed that the transmitter would be located separate from the studio, with its own building, at its own site.

First there is a large studio, the size to be determined by just what type of programs one wants to originate. The associated technical facilities suggested will handle choral groups, full orchestra, audience-participation programs, etc.

Then there is the main control room equipped with a dual-channel control console. These two full channels, each with its own monitoring amplifier and power supply, provide maximum fexibility and reliability. Two three-speed turntables and two automatic turntables are employed. Two remote-controlled tape recorders and two monitor speakers together with miscellaneous amplifiers and accessory items are included.

A highlight of this plan is the inclusion of a multipurpose room. It may be a small studio or, as it is shown equipped (Fig. 1-11), may serve many purposes as follows:

1. A subcontrol room serving the main studio for regular programming auditions or recording (see Fig. 1-12)
2. For disc-jockey-type shows

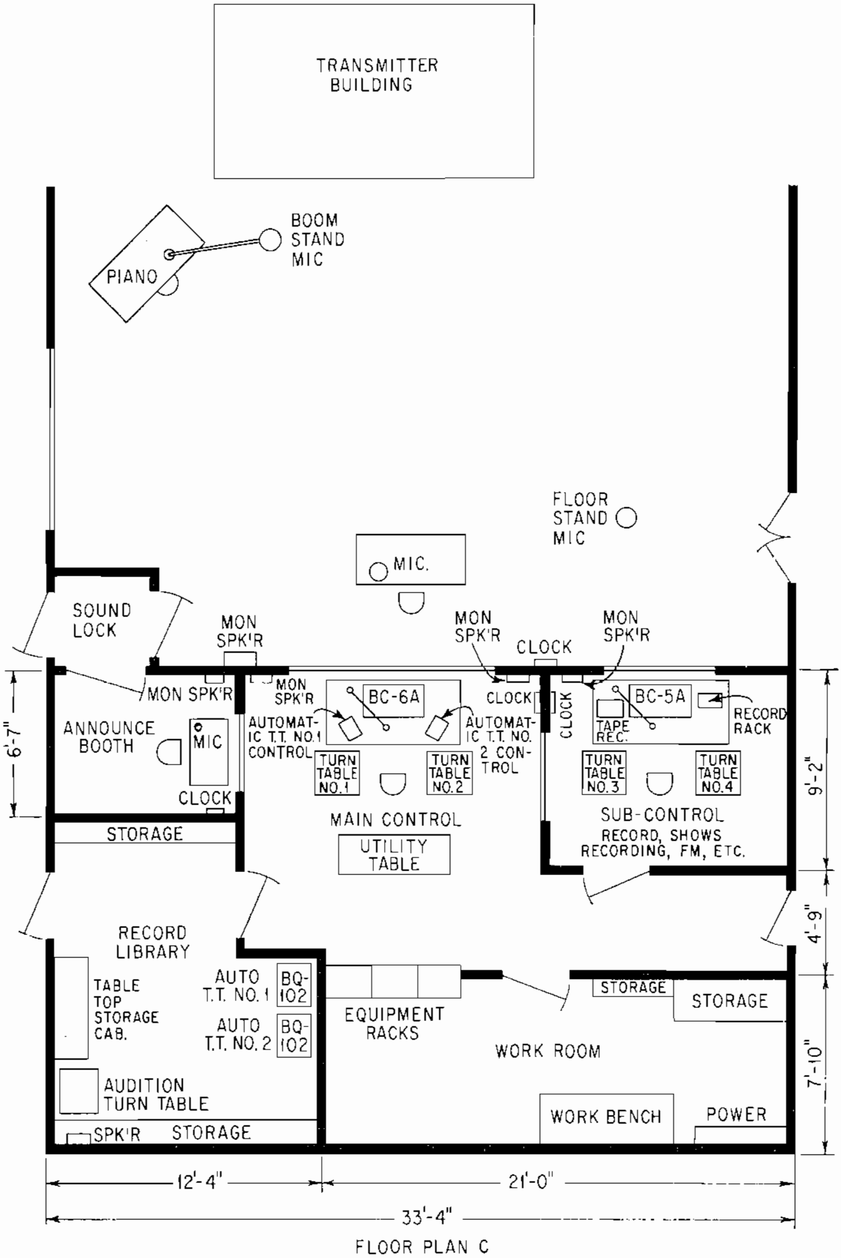


Fig. 1-11. Floor plan *C:* location of all major equipment items. Note that the transmitter is separated from the studio location.

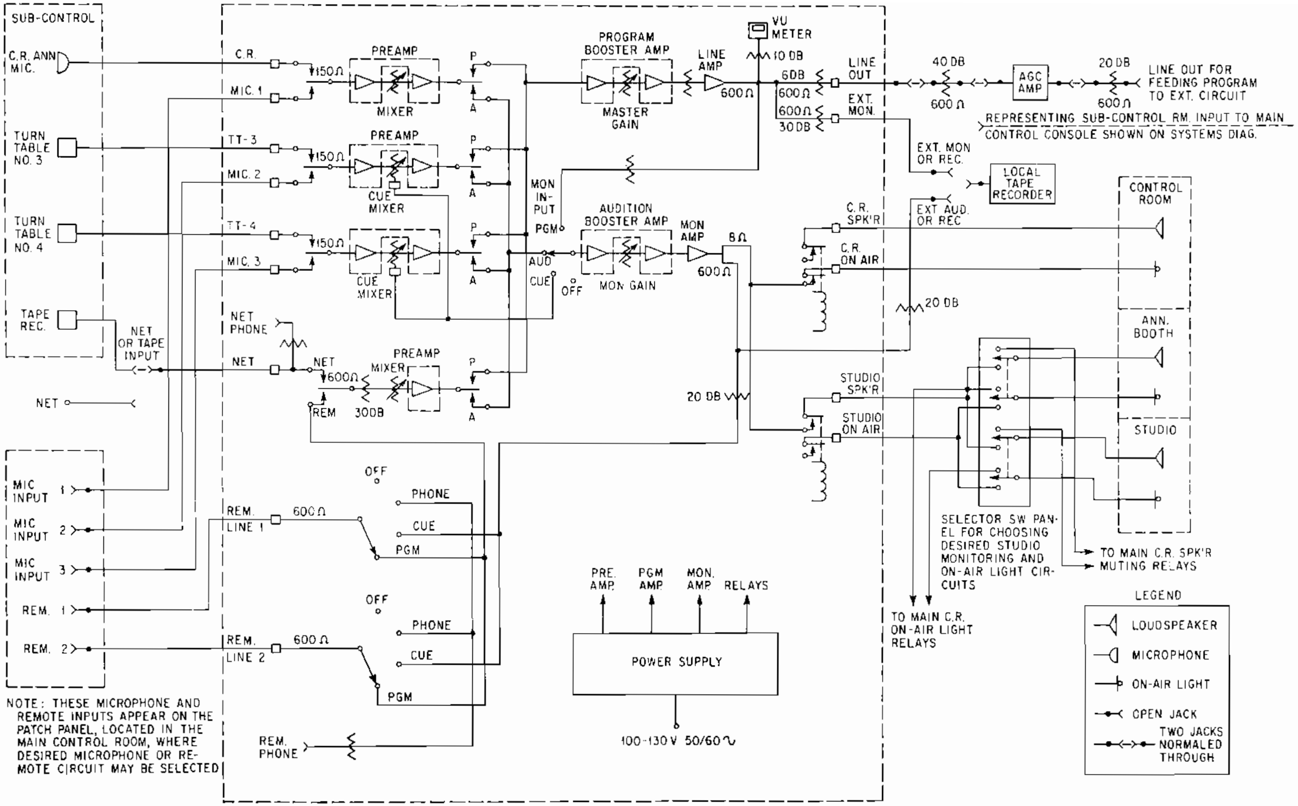


FIG. 1-12. Subcontrol block diagram for plan *C*.

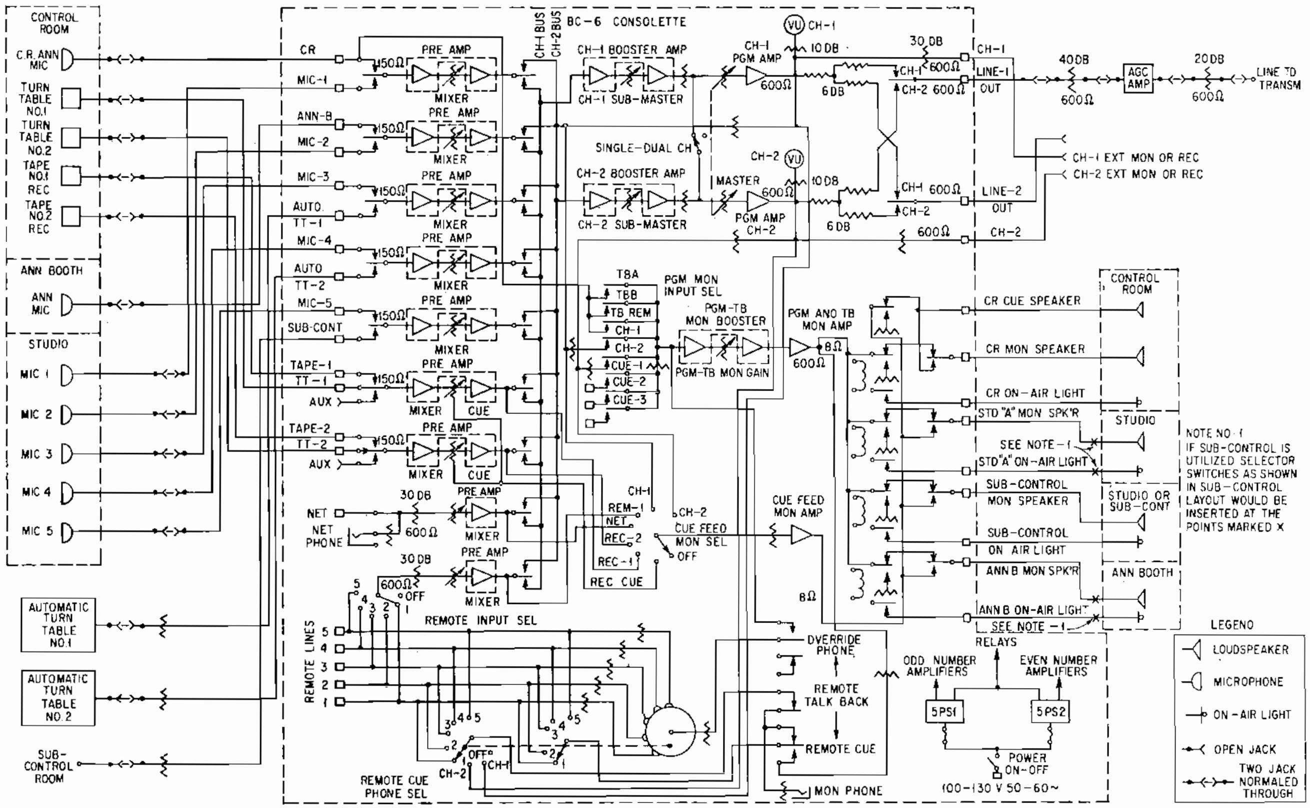


Fig. 1-13. Main control room of plan C and associated equipment.

3. For separate programming of another channel such as FM or to another AM station
4. As a recording control room
5. Announce booth
6. Auditioning special programs
7. Standby
8. As a program "make-up" facility for automatic program utilization in the future.

The announce booth, record library, engineering workroom, and storage area follow closely the preceding plans.

Technical Facilities of Plan C

The major equipment item new to this plan is the dual-channel control console. A block diagram of the unit is shown within the system diagram in Fig. 1-13. It has 22 inputs available, a "split-mixer" fader system, and two VU meters.

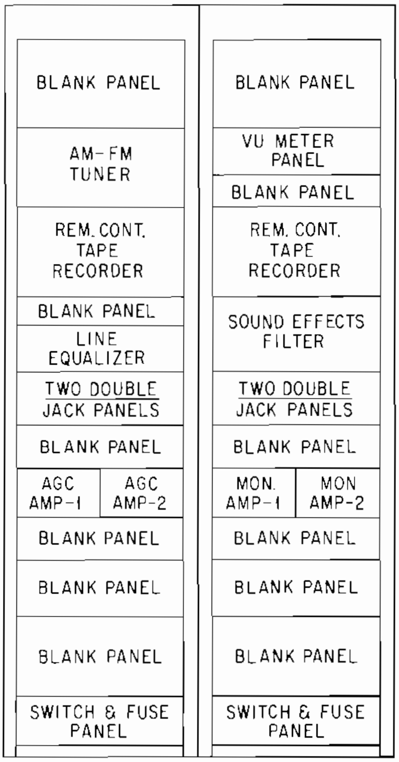
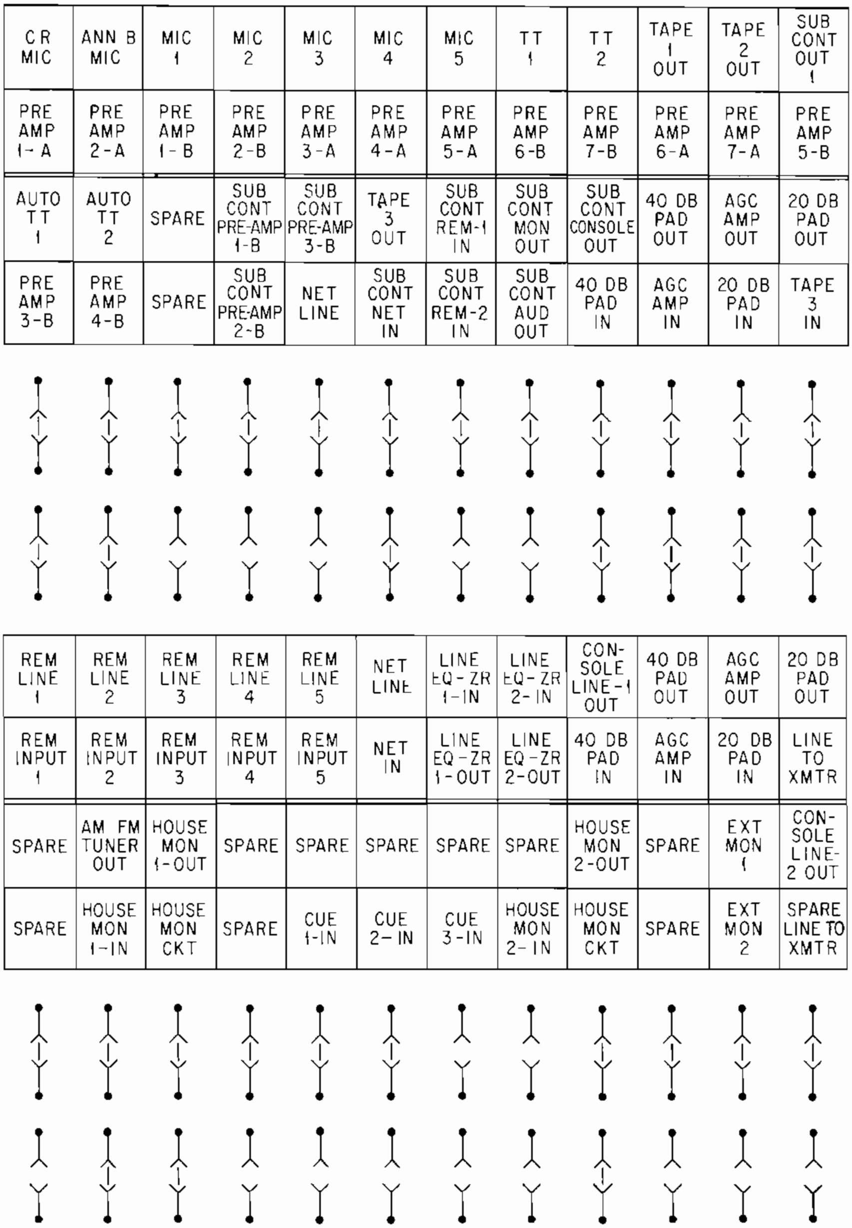


FIG. 1-14. This shows the necessary rack equipment for plan C with several desirable optional items: AM-FM tuner, line equalizer, VU meter panel, and sound-effects filter.

As used in plan C system this consolette is made to serve on command as a master control; a "combo," or operator-announcer's control board; and a program on one channel while running an audition or recording on the other. Figures 1-14 and 1-15 show that the rack layout for Plan C is as given in Table 1-3.

At the beginning of this part it was stated that the plans did not necessarilly represent any existing stations but that they illustrated several ways in which the equip-



CR MIC	ANN B MIC	MIC 1	MIC 2	MIC 3	MIC 4	MIC 5	TT 1	TT 2	TAPE 1 OUT	TAPE 2 OUT	SUB CONT OUT 1
PRE AMP 1-A	PRE AMP 2-A	PRE AMP 1-B	PRE AMP 2-B	PRE AMP 3-A	PRE AMP 4-A	PRE AMP 5-A	PRE AMP 6-B	PRE AMP 7-B	PRE AMP 6-A	PRE AMP 7-A	PRE AMP 5-B
AUTO TT 1	AUTO TT 2	SPARE	SUB CONT PRE-AMP 1-B	SUB CONT PRE-AMP 3-B	TAPE 3 OUT	SUB CONT REM-1 IN	SUB CONT MON OUT	SUB CONT CONSOLE OUT	40 DB PAD OUT	AGC AMP OUT	20 DB PAD OUT
PRE AMP 3-B	PRE AMP 4-B	SPARE	SUB CONT PRE-AMP 2-B	NET LINE	SUB CONT NET IN	SUB CONT REM-2 IN	SUB CONT AUD OUT	40 DB PAD IN	AGC AMP IN	20 DB PAD IN	TAPE 3 IN

REM LINE 1	REM LINE 2	REM LINE 3	REM LINE 4	REM LINE 5	NET LINE	LINE EQ-ZR 1-IN	LINE EQ-ZR 2-IN	CONSOLE LINE-1 OUT	40 DB PAD OUT	AGC AMP OUT	20 DB PAD OUT
REM INPUT 1	REM INPUT 2	REM INPUT 3	REM INPUT 4	REM INPUT 5	NET IN	LINE EQ-ZR 1-OUT	LINE EQ-ZR 2-OUT	40 DB PAD IN	AGC AMP IN	20 DB PAD IN	LINE TO XMTR
SPARE	AM FM TUNER OUT	HOUSE MON 1-OUT	SPARE	SPARE	SPARE	SPARE	SPARE	HOUSE MON 2-OUT	SPARE	EXT MON 1	CONSOLE LINE-2 OUT
SPARE	HOUSE MON 1-IN	HOUSE MON CKT	SPARE	CUE 1-IN	CUE 2-IN	CUE 3-IN	HOUSE MON 2-IN	HOUSE MON CKT	SPARE	EXT MON 2	SPARE LINE TO XMTR

Fig. 1-15. Jack panels for plan *C*.

ment could be arranged and that the plans or combinations of them would satisfy a majority of cases. As plan *C* is examined, it becomes evident that some of these features would readily adapt themselves to Plan *B*. With the cross-application possibilities of these plans, practically all programming requirements can be met.

Table 1-3. Plan *C* Equipment List [*]

Quantity	*Main control room*
1	Dual-channel audio consolette with tubes and additional speaker light relay
1	Dual headphone
1	Microphone
1	Microphone mounting
1	Microphone plug
1	Microphone receptacle
2	"On-air" lights
2	Three-speed turntables
2	Transcription tone arms
2	Pickup heads
2	Transcription equalizers or filters
2	Tape recorders, remote control, rack mounting
2	Cabinet racks
2	40-db 600-ohm fixed pads
2	AGC program amplifiers with tubes
2	Monitor amplifiers with tubes
2	Mounting shelves
2	Monitor speakers
2	Monitor-speaker housings
2	Speaker-matching transformers
1	16-in. sessions clock
4	Double-jack panels
2	Double-jack panel mats
8	Audio patch cords, 2 ft in length
1	AM-FM tuner
2	Line equalizers
1	VU-meter panel
1	Sound-effects filter
2	Terminal board mounting brackets
2	Terminal power strips
2	Terminal audio blocks
2	Switch and fuse panels
4	$10\frac{15}{32}$-in. blank panels
1	$1\frac{23}{32}$-in. blank panel
4	$5\frac{7}{32}$-in. blank panels
2	$8\frac{23}{32}$-in. blank panels
2	$3\frac{15}{32}$-in. blank panels
200 ft	Interconnecting cable No. 22 AWG shielded pair with cotton-braided outer cover
400 ft	Interconnecting cable for audio rack wiring No. 20 shielded pair, solid conductor
200 ft	Interconnecting cable for a-c and filament circuits No. 18 shielded pair, stranded conductor

Quantity	*Studio and announce booth*
1	Pressure microphone
2	Ribbon microphones
1	Floor stand
1	Microphone boom stand
2	Uniaxial microphones
4	Desk stands
8	Microphone receptacles
8	Microphone plugs
3	"On-air" lights
2	Studio monitor speakers
2	Monitor-speaker housings
2	Speaker matching transformers
1	16-in. clock
300 ft	Interconnecting cable No. 22 AWG shielded pair, with cotton-braided outer cover

	Record library
2	Automatic turntables with remote control
1	Turntable
1	Transcription tone arm
3	Pickup heads
3	Transcription equalizers and filters
2	Utility amplifiers
1	Monitor amplifier for audition
1	Plug-in transformer
1	Selector switch for input of amplifier
1	Monitor speaker for audition
1	Monitor-speaker housing
150 ft	Interconnecting cable No. 22 AWG shielded pair, with cotton-braided outer cover

	Multipurpose room equipped as studio
1	Pressure microphone
1	Microphone mounting
2	Microphone plugs
2	Microphone receptacles
2	"On-air" lights
1	Monitor speaker
1	Monitor speaker housing
1	Speaker matching transformer
1	16-in. clock
50 ft	Interconnecting cable No. 22 AWG, shielded pair, with cotton-braided outer cover

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[*] Transmitter and antenna equipment are not listed here, since they are specified in accordance with power and pattern.

Quantity	*Multipurpose room equipped as a subcontrol room*
1	Single-channel audio consolette with tubes
1	Dual headphone
2	Three-speed turntables
2	Transcription tone arms
2	Pickup heads
2	Transcription equalizers and filters
1	Tape recorder
1	Input transformer for tape recorder
1	Output transformer for tape recorder
100 ft	Interconnecting cable No. 22 AWG, shielded pair, with cotton-braided outer cover

HOW TO DESIGN THE COMBINATION CONTROL ROOM-ANNOUNCE BOOTH TO GIVE GOOD ACOUSTICAL PERFORMANCE [1]

Many present-day radio control rooms are not only used for this purpose but also act as announce booths where most of a station's announcing is carried on. In many cases the control room may be the only studio area in a station, and it will contain all the audio equipment of the station. Frequently, a transmitter and a record library will also be located in the control room. This makes the problem of acoustics more complex, but since radio sells with sound, good acoustics are a must when the best sound possible is desired.

Design Factors

Combination control rooms are at best a compromise of the several design factors. In the design of this control room, consideration must be given to the following:

1. Location of the control room within the studio building
2. Isolation—elimination of unwanted sound and noise, both internal and external
3. Construction—dual wall, floating wall, single wall
4. Reverberation control, elimination of unwanted reflections, and floor treatment
5. Ventilation and air conditioning
6. Size and arrangement of equipment

Location

The combination control room must be located so that it is convenient to the office areas, but traffic in and out of the room should be minimized in order to reduce distractions to the announcer. The location selected must have as little external acoustical and electrical noise as possible. The control room should be located away from street noise or noise that may be generated in other parts of the building, because it may become difficult and costly to reduce unwanted noise that enters through the floor and walls. Air-conditioning compressors and other rotating machinery should be well isolated and kept as far away from the control room as possible.

It is not wise to locate a control room next to a power-transformer vault or other large electrical equipment that may produce strong electrical fields. These strong electrical fields may cause noise problems in audio equipment. If the control room contains the transmitter, great care should be given to the grounding of all audio equipment, including equipment racks, consolettes, turntables, pickup arms, and other metal objects. In some cases, it may be desirable to shield the control room with copper screen to reduce noise generated from high-power RF fields of the nearby transmitters and antennas.

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[1] *RCA Broadcast News*, vol. 100, April, 1958.

Isolation

Ideally, a control room should be a sound-isolated room within a room. Cost considerations in a small station may make such construction impractical, but it should be considered when possible. The floors and walls should be built from materials that will minimize the transfer of sound into the control room. Many new stations use concrete block walls and concrete slab floors that are isolated from the building walls with asphalt-impregnated glass fiberboard. This type of floor construction is very practical, since it reduces outside vibration in the control room floor.[2] A stable floor will improve turntable operation by reducing vibration that enters the pickup system from external sources.

Construction

The ideal control-room wall would consist of either a dual masonry wall or a masonry wall with a sound-isolated floating inner wall.[3] In the smaller stations, cost considerations usually preclude this type of construction. A single wall of masonry, cement, gypsum, or pumice block is a good compromise, which is completely satisfactory where external noise is reasonably low.

Wood-wall construction should not be used unless double walls are used. Staggered 2- by 4-in. studs can be set on 16-in. centers on a 2- by 6-in. plate for the double-wall construction (see Fig. 1-16). Rock-wool bats can be interlaced between the studs for additional sound isolation. There should be at least 2 in. of rock wool or other sound-absorbing material above the ceiling surface, and if external noise is of large magnitude, the ceiling should be sound isolated.

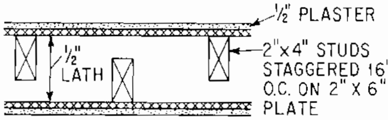

FIG. 1-16. A cross section of a sound-insulating partition. Wooden walls should be constructed in this manner to reduce external noise.

If care has been given to the location of the control room in a given building, the offices and other quiet areas surrounding the control room may screen it from unwanted sound. Control-room doors should be the heavy soundproof type (see Fig. 1-17), or double doors should be used. Observation windows should be kept to a minimum. Each such window should consist of two panes of heavy plate glass of different thicknesses to break up resonance conditions. The glass plates should be set in rubber or felt gaskets, and usually the glass plates are set about 10° off vertical (see Fig. 1-18).

Reverberation Control

Some form of reverberation control should be employed within the studio. If a studio has too long a reverberation period, the sound may blur and speech may lack intelligibility. Such sound characteristics are not pleasing to the listener. Generally a studio should have an approximate reverberation time of 0.4 sec for a volume of 1,000 cu ft rising to 0.6 sec for 10,000 cu ft[4] (see Fig. 1-20). The reverberation time should be about the same from 100 to 5,000 cycles, but it may rise slightly at 5,000 cycles (see Fig. 1-19). This type of studio characteristic helps eliminate low-frequency boominess.[5] An acoustical consultant should design the studio and supply the proper materials.

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[2] Impact Noise Isolation in Television Studios, *Broadcast News*, vol. 97, October, 1957.

[3] Michael Rettinger, "Applied Architectural Acoustics," Chemical Publishing Company, Inc., New York.

[4] NBC Studio Design, *J. Acoust. Soc. Am.*, vol. 8, p. 31, 1936.

[5] Edward J. Content and Lonsdale Green, Jr., Acoustical Design and Treatment for Speech Broadcast Studios, *Proc. IRE*, vol. 32, no. 2, February, 1944.

Consideration should be given to all wall and equipment surfaces in the control room in order to eliminate unwanted reflections. Perforated hardboard or Transite can be used for wall coverings with rock or glass wool placed behind it for sound absorption (see Fig. 1-21). Hardboard may be painted, and it is easily maintained with occasional washing. The hardboard can be used for wall panels set at various small angles of 5 to 10° to produce greater diffusion of sound.

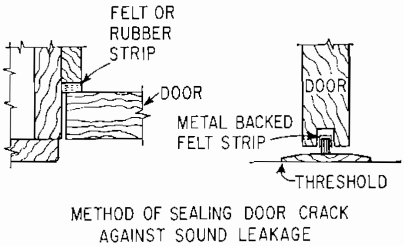

Fig. 1-17. Normal methods for sealing the control-room door. The door itself should be of a heavy type to improve isolation of the control room.

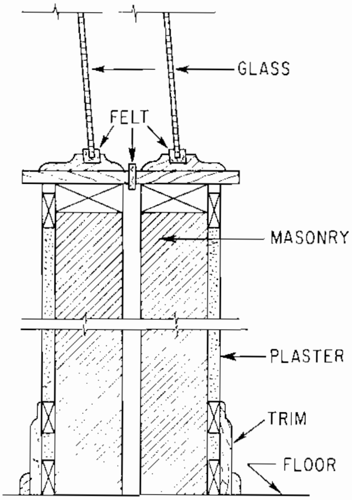

Fig. 1-18. Sound-insulating window construction showing structural separation of double wall. Glass windows in studios and control rooms should be offset about 10°, and they should be mounted as shown on a double wall.

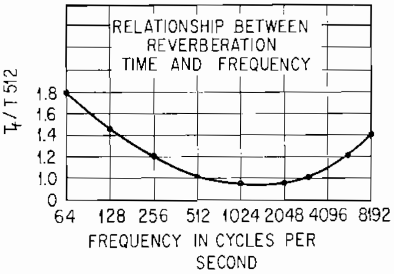

Fig. 1-19. Morris-Nixon curves showing the relationship between reverberation time and frequency. Reverberation time should remain fairly constant between 100 and 5,000 cycles.

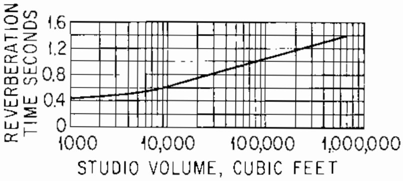

Fig. 1-20. Variations in reverberation time as the size of the room increases with a 512-cycle reference signal.

All glass surfaces should be set on an angle to reflect sound into the sound-absorbing surfaces of the ceiling. Glass surfaces should be kept to a minimum, and large corner areas of glass should be avoided. The floor covering should be of a soft material, such as cork or vinyl tile, to reduce surface noise. A rug may be necessary to produce the required deadening in control rooms having many glass surfaces and other reflecting areas. The surface of the operating table should be made of a soft material such as linoleum or vinyl. This will reduce table-top noise.

Microphone Requirements

A good microphone with proper directional characteristics is important in the control room. A 77-DX microphone operated in a unidirectional pattern has excellent properties (see Fig. 1-22). The BK-5A microphone is also an excellent microphone for the control room. The distance between the speaker and the microphone will be determined by the acoustics of the control room; however, good microphone technique is important for all personnel if natural reproduction is desired.

Ventilation

To do a good selling job, an announcer must sound alive. It is important to provide air conditioning and ventilation so that announcers have a good environment in which to work. A central air-conditioning system is recommended. The air is brought in through ducts from the coolers. The air ducts should be lined with a sound-absorbing material for a distance at least twenty times the average width of the duct. A separate duct should be run to each studio and to each control room to avoid sound transfer through the ducts. Low-velocity air should be used to prevent air noise from the duct openings.

If the control room contains a transmitter, it is usually possible to exhaust hot transmitter air to the outside and to cool the transmitter with spent room air. If this is not possible, the transmitter should be partitioned off from the control room, and a separate source of air should be used to cool the transmitter. The transmitter can be remotely controlled if it is in another room some distance from the control operation. Such a procedure will save many dollars in construction costs and also eliminate a source of noise in the control room.

Equipment Arrangement

The equipment selected will, to a large extent, determine the physical aspects of the control room. The control room should be large enough to contain all required personnel and equipment. At the same time thought should be given to possible future expansion, and extra space should be provided with this in mind. A control room that is a little larger than necessary at the outset makes it easily expanded later. Furthermore, it is always more difficult to treat a small room acoustically than a large room.

Planning It Right

A good architect should be consulted when planning a studio-control room. After a general station plan is formulated and equipment selected, the architect and the consulting engineer should work out the specific construction details for the station. Careful acoustical planning combined with good equipment will enhance the sound of any station and make its sound sell more.

ROOM ACOUSTIC DESIGN

Foreword

The third edition of the "NAB Engineering Handbook" contained a reprint of a paper presented by Mr. John E. Volkmann before the Acoustical Society of America in New York, entitled "Polycylindrical Diffusers in Room Acoustical Design." Mr. Volkmann prepared another paper entitled "Acoustic Recommendations for Small Combined Studio, Scoring Stage and Review Room" which although it was prepared originally for motion-picture studios provides data of interest in the construction of television studios.

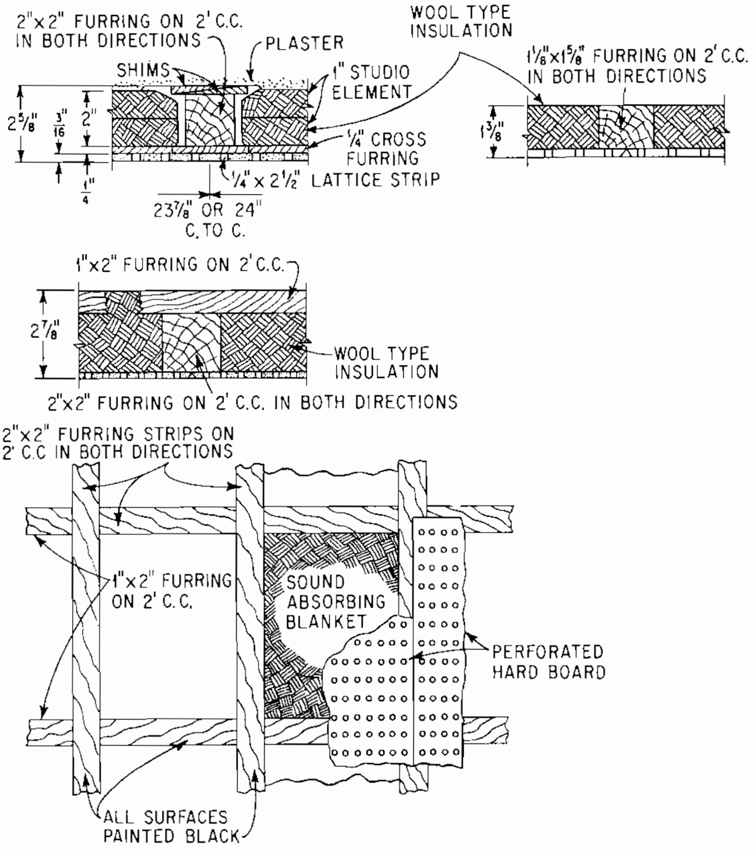

Fig. 1-21. Typical acoustical panels and how they are mounted. Excellent isolation can be obtained if this type of wall material is backed up with glass or rock wool.

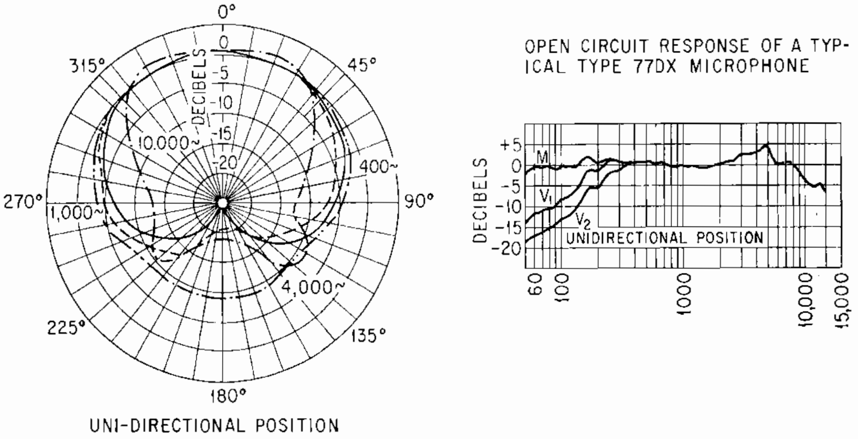

Fig. 1-22. Response curve for the RCA type 77-DX microphone. A good microphone is necessary for combination control rooms.

The NAB Department of Engineering, with the permission of Mr. Volkmann and RCA, has combined the two papers to provide informational data useful in the design of studios used for AM and FM broadcasting as well as for television broadcasting and recording.

Basic Requirements and Definitions

Although large-scale recording and projection operations usually require separate rooms for optimum acoustic results, economic considerations frequently necessitate the combining of these facilities into one studio and the primary purpose of these recommendations is to provide the basic information necessary to accomplish this objective. The proper planning and acoustic design of a studio before construction have received ever-growing attention by architect and engineer and have eliminated much of the necessity for the curative treatment of acoustic defects.

Good Acoustics

The requirements for good acoustics have been stated by Wallace Clement Sabine, pioneer in architectural acoustics, in his book referenced in the bibliography. The criterion most frequently used for judging the acoustic excellence of a room is its optimum reverberation time. Other factors and acoustic phenomena with which the scientist or acoustical engineer is concerned in determining the acoustical performance of a room include the following: echo, resonance, interference pattern, sound absorption, reflection, transmission, diffuse sound, rate of decay, intensity distribution, sound level, and noise level.[6]

Experience in rooms with wood paneling and sound-diffusing surfaces indicates that the manner in which the reverberant and other aftersounds in a room are distributed has possibly as much to do with the acoustical excellence of a room as the actual time of decay in the room, and from time to time we have heard discussions on the diffusion of sound in rooms not only in regard to fulfilling the assumptions in the Sabine reverberation formula but in regard to its subjective effect.

Physical Design Factors

The major physical factors with which the architect is concerned in the acoustical design of a studio are as follows:

1. Choice of site
2. Size of studio
3. Shape and proportions of studio
4. Selection and placement of absorbing materials
5. Sound and vibration isolation

The broadcasting and recording engineers are also interested in the placement of microphones and loudspeakers and in variable reverberation control.

General Considerations

Since most room acoustic difficulties occur due to reverberation and other reflection phenomena, a brief discussion of these general factors and their control is considered important to a proper understanding of acoustical design.

Reverberation

The action of sound when confined in an enclosure is much more complex than its action in free air. In free air only the direct sound from the source can be heard. In a room, however, the sound one hears is composed of both the direct and the reflected waves. The sound wave generated in the room proceeds or expands spheri-

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[6] See Appendix A for definitions of acoustic terms.

cally from its source until it meets the boundary surfaces, where it suffers partial reflection, absorption, and transmission. The reflected wave from each surface continues its travel inside the room only to suffer again partial reflection, absorption, and transmission each time it strikes a boundary surface. This process is repeated until the sound energy is completely dissipated. In an ordinary room with plaster walls and ceiling, an ordinary sound may undergo from 200 to 300 such reflections before its energy is completely dissipated by absorption or transmission. If we recall that sound travels 1,120 fps, it is readily seen that the duration of this prolonged aftersound, called the reverberation time of the room, may be several seconds for a large room where the mean free path is long. The effect of excessive reverberation is to blur speech and music owing to the overlapping of successive sounds.

The reverberation time of a room, which is the time required for a sound of given initial intensity to die away to the threshold of minimum audibility, depends directly on the intensity level of sound and the size of the room and depends inversely on the absorption in the room. The standard reverberation time of a room is the time obtained when using an initial intensity of 1,000,000 times the intensity at minimum audibility. Increasing the size of a room increases the reverberation period owing to the fewer number of reflections which occur in it during a unit interval of time.

Optimum Size of Studio

Just as tradition and experience have taught that an optimum reverberation time exists for each size of room, so we have learned that an optimum size of studio exists for each type and size of orchestra. The data in Table 1-4 are based on commercial practices and subjective listening tests. The column labeled "auditorium practice" shows the minimum number of orchestral instruments recommended for auditoriums, while the column labeled "broadcast practice" gives the maximum number of instruments sometimes crowded into broadcast studios. The recommended practice for recording and scoring studios is shown in the column labeled "optimum." Experience in Hollywood indicates that a volume of 50,000 cu ft constitutes about the minimum requirements for scoring studios. Another acoustical factor which, in the case of sound-picture projection, is related to the size of room is the acoustical power required for proper sound reproduction. Most sound motion-picture reproducing equipment is more than adequate for the ordinary-size review room; however, in those cases where the picture is reviewed in a theater, the reproducing equipment should meet the "Minimum Power Requirements for Theatres" established by the Academy Research Council.

Table 1-4. Size of Orchestra vs. Room Size

Volume of room, cu ft	*Auditorium practice*	*Optimum*	*Broadcast practice*
10,000	–	6	12
20,000	6	9	25
50,000	9	21	50
100,000	19	38	130
200,000	31	70	250

From the standpoint of reverberation time, minimum power requirements, air-conditioning-system requirements, etc., the theater which is used for reviewing purposes should be made a minimum in size compatible with its seating capacity and architectural treatment. Small review rooms and scoring rooms on the other hand should be made as large as possible to most nearly approximate auditorium and hall conditions. For normal theater sizes the Academy of Motion Picture Arts and Sciences recommends 125 cu ft per seat. For small rooms, say with a seating capacity of only 20, this figure can be increased to as much as 500 cu ft per seat.

Room Resonances—Effect of Parallel Reflecting Surfaces

When sound is generated between two parallel reflecting surfaces, "standing waves" are set up at certain frequencies depending on the distance between the surfaces. The lowest frequency at which the standing-wave resonance will be set up is that frequency for which its wavelength equals twice the distance. The parallel surfaces will likewise cause resonance for harmonic frequencies. Thus, for a flat reflective ceiling whose height is 11.2 ft above floor level, resonance may occur at 50, 100, 150 cycles, etc. (frequency equals 1,120 divided by wavelength, that is, by twice the ceiling height).

The effect of these resonances is twofold: First, it introduces frequency discrimination in the form of peaks and dips in the response characteristic, and second, it introduces a persistence, or hanging-on effect, in the sound for frequencies at or near resonance. This frequency discrimination and persistence gives a hollow-sounding characteristic, especially if the resonance frequencies are widely separated (surfaces close together), which is generally the case in small rooms.

The effects of standing-wave resonances can be minimized or controlled by any or all of three methods: (1) by absorption treatment, (2) by changing the position or spacing of the surfaces, and (3) by changing the shape of the reflecting surfaces. In general, the first method is not satisfactory in small studios, since the absorption required for damping the resonances is too great from the viewpoint of optimum reverberation and hence causes the room to sound "dead" and, if the absorption material is selective, may cause it to sound "bassy." The other two methods will be discussed under separate paragraphs later.

Structural Resonance

The phenomenon of resonance, or the ability to vibrate most easily at certain frequencies, may occur in structures as well as in the air in rooms. Structural resonance usually is not harmful unless the resonant body is closely coupled mechanically to the source of sound. As discussed later, structural resonance is sometimes a virtue; for example, the resonance of wood paneling in an auditorium is often a factor which improves its acoustic excellence, especially for music. In this case, however, the fundamental and harmonic resonances do not occur at any one frequency bnt rather over many different frequencies owing to variations in size and construction of the individual wood panels.

Shape of Studio—Preferred Proportions

To minimize the frequency-discrimination effect caused by the standing-wave systems set up between parallel surfaces in a room, it is desirable to choose major dimensions which are not integral to one another. By proportioning the three major dimensions of a room in the ratio of the cube root of 2 (or in ratio of multiples of the cube root of 2), a good distribution of the natural resonance frequencies is obtained. For small rooms the preferred ratio of height to width to length is 1 to 1.25 to 1.6 as shown in Fig. 1-23. For the studio of average size and shape the preferred dimensions should be in the ratio of 1 to 1.6 to 2.5. In all cases the dimensions shown are derived from the ratio of the 3/2. Stating it another way the major dimensions should be separated 1/3 octave with respect to one another, or other ratios derived from this fundamental ratio by shifting any or all of the dimensions by one or more integral octaves can be used. Other preferred proportions for less common shaped rooms are also shown in Fig. 1-23.

We next deal with the shape and treatment of individual surfaces.

Shape of Reflecting Surfaces—Sound Diffusion

A pleasing reverberation characteristic depends not only on the proper reverberation time but on a uniform rate of decay of sound. This requires a diffuse distribution of the aftersound in a room and can be obtained by shaping and paneling the walls, ceiling, and other surfaces so as to disperse their reflections in all directions. Many rooms and halls known for their acoustic excellence have such wood paneling and sound-diffusing surfaces. For example, in the Philadelphia Academy of Music, which has several tiers of boxes and wood paneling throughout the auditorium, the dimensions of the projecting surfaces, being comparable to the wavelength of sound, tend to disperse the reflections and give a more diffuse distribution of sound. An important point regarding sound diffusion is that it does not lessen the total energy in the room but merely tends to increase the number of reflections which occur per unit time and hence lessens the intensity level of the individual reflections. Because the difference in intensity level between reflections is less, the decay of sound in the room tends to be smoother and more uniform and hence more pleasing to a listener. This factor is also of practical importance in making the placement of microphones less critical.

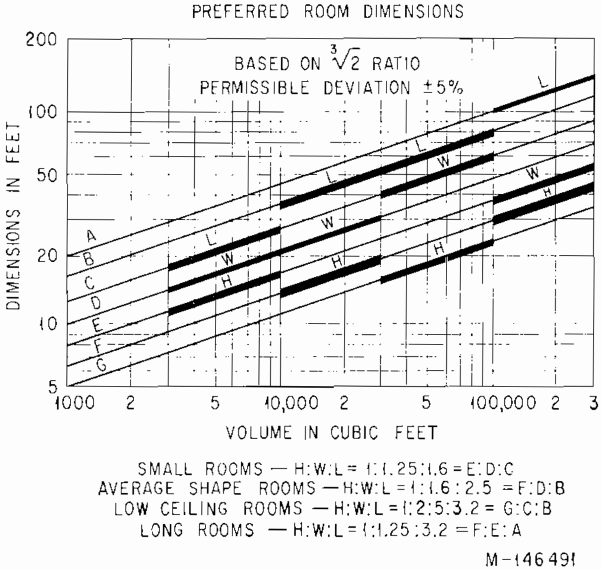


Fig. 1-23. Preferred studio dimensions.

A second factor of importance in these famous music rooms is that the wood paneling also helps to give a diffuse distribution of sound by virtue of the fact that the energy incident on its surface which is not absorbed is reradiated.

This reradiated energy does not follow the regular law of equal angle of incidence and reflection but, owing to panel vibration, acts more like a loudspeaker diaphragm and, therefore, for most frequencies either disperses the incident energy over a wide angle or changes its direction. A third important factor in these rooms is that the radiation from the wood paneling occurs farther owing to direct mechanical or "telephonic" transmission from the original sound sources on the stage through the wood flooring and panel-mounting structure. Since the wood panels are more or less of different sizes and shapes, the panel resonance frequencies are not selective. Two other interesting facts to note here are that panel radiators have a decay time of their own and that the transmission time in wood is much shorter than in air.

This "diffuse" distribution of energy coming from many random directions and from a great number of small sources of sound in the room has, in addition to giving a more uniform distribution and decay of sound, the important psychological effect

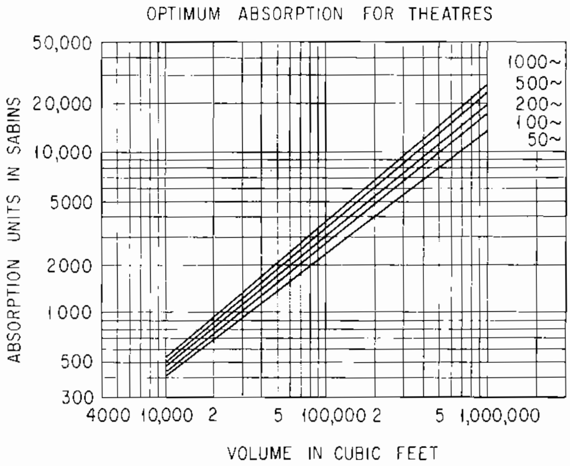
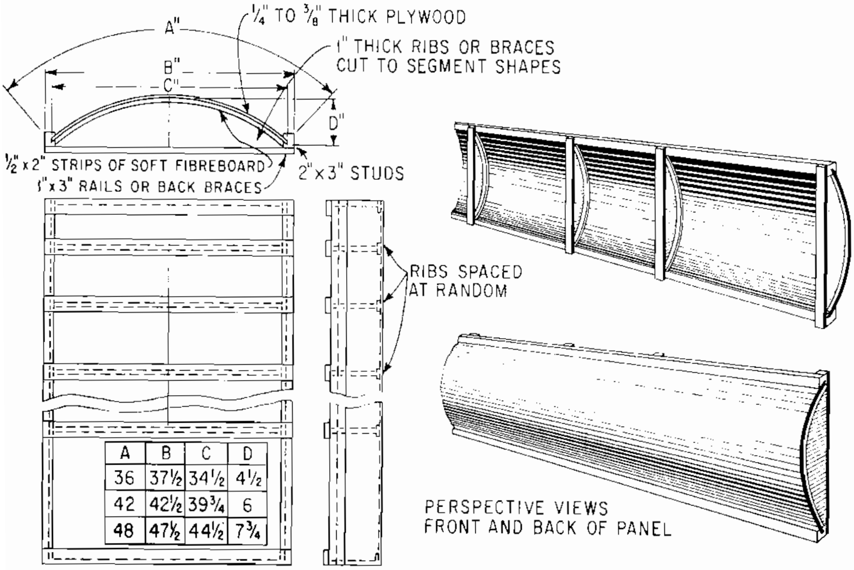


Fig. 1-24. Optimum absorption.



A	B	C	D
36	37½	34½	4½
42	42½	39¾	6
48	47½	44½	7¾

Fig. 1-25. Convex wood panel.

created by enveloping the listener with sound, which gives a certain feeling of body or depth to the sound. This "feeling" effect of sound is further enhanced by the transmission of sound through the wood floor to the seats and from other structures in the room.

Sound-absorption Characteristics

The sound-absorbing materials used for the control of reverberation and delayed reflections should have adequate efficiency at the low frequencies to give the optimum reverberation characteristic for the specified room size (see Fig. 1-23).

The optimum sound-absorption units vs. frequency corresponding to the optimum reverberation times for various room volumes is shown in Fig. 1-24.

Convex Wood Panels

Figure 1-25 shows a typical curved wood panel consisting of 4- by 8-ft plywood formed over curved segment braces and fitted at the edges with 2- by 3-in strips which have been routed and held together with 1- by 3-in. back braces. The segment braces, which must be spaced at random, have strips of ½-in. Celotex or other soft fiberboard placed between them and the paneling to prevent rattles. It is felt that convex cylindrical wood paneling is particularly suited to meet the aforementioned requirements of a good sound diffuser because it disperses sound energy not only by reflection from its curved surface but by radiation due to its resonance action or panel vibration which, as already mentioned, is set up either by direct transmission from the original source of sound or by partial absorption and reradiation of the aerial sounds impinging on its surface.

Dispersion by reflection depends on the size and curvature of the panels and their relation to the wavelength. Dispersion characteristics for a curved and flat panel plotted on polar coordinates are shown in Fig. 1-26. This shows clearly the diffusing action of convex curved surfaces and was obtained by rotating the panel about its long axis while keeping the source and directional pickup constant.

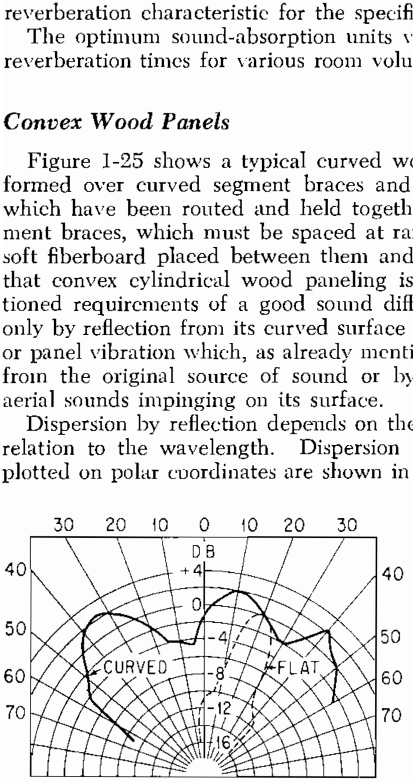
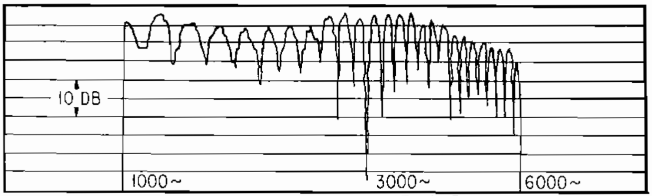


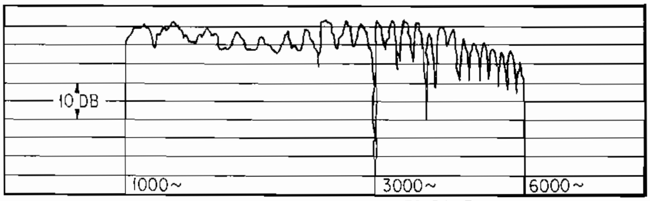
Fig. 1-26. Polar distributions from convex and flat panels.

It should be noted here that the apparent source for convex reflectors is always behind the surface. The value of such surfaces in reducing the interference effect of first reflections as compared with flat surfaces is shown in Fig. 1-27. Note that the aiding effect at some frequencies and the cancellation at others is less for the convex panel. The relative intensity levels of the direct and reflected waves used in obtaining the interference curves are shown in Fig. 1-28. The reduction in interference effect is significant when we remember that the total energy content of the reflected wave from either surface remains the same. As mentioned earlier, the reduction of the interference effect of first reflection is important in studio microphone pickup in allowing greater freedom of placement. For remote surfaces in large rooms a similar diffuse reflection can be obtained by means of concave reflectors providing the focus point or the apparent source of sound, which in this case is in front of the reflector, is not within or near the seating area or any other critical area.

Dispersion of sound by means of panel resonance depends on the modes of vibration set up. For areas of motion small compared with the wavelength radiated, the distribution will tend to be nondirectional. For vibrations normal to the surface, a convex cylindrical panel would tend to set up a cylindrical wavefront as compared with the plane wavefront in the case of flat panels. The resonance frequencies and response of a panel depend on a great number of factors such as the damping co-

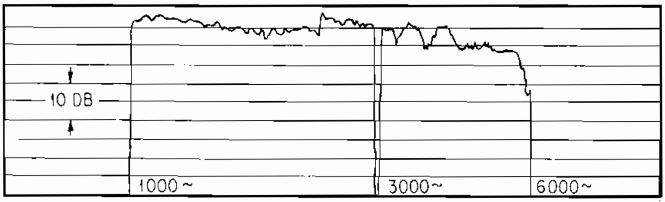


INTERFERENCE WITH FLAT PANEL

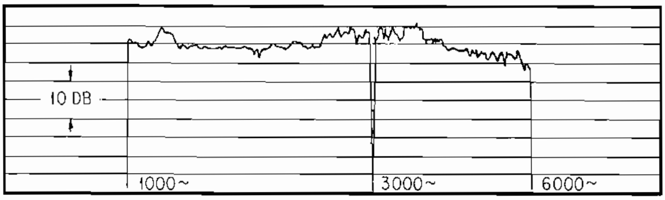


INTERFERENCE WITH CURVED PANEL

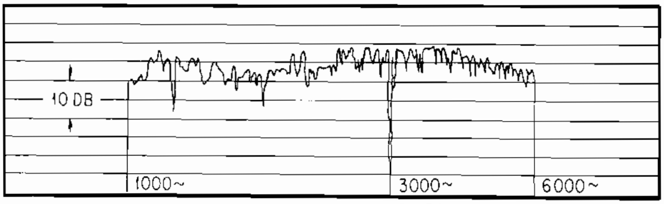
FIG. 1-27. Interference between direct and reflected waves for convex and flat panels.



DIRECT SOUND



REFLECTION FROM FLAT PANEL



REFLECTION FROM CURVED PANEL

FIG. 1-28. Direct and reflected response of panels used in interference measurements.

efficient of the material, thickness, spacing of braces, method of mounting of the entire panel, etc. It is interesting to note that because of the added stiffness introduced by bending, a smaller panel thickness can be employed for curved panels for the same frequency. The decay time, or "resonance time," of a typical panel excited at one of its modes of vibration is shown in Fig. 1-29. In addition to the dispersion and radiation action, the vibration of the wood paneling aids the absorption efficiency over more rigid materials. Preliminary data indicate a coefficient of approximately 0.18 over a considerable band of frequencies.

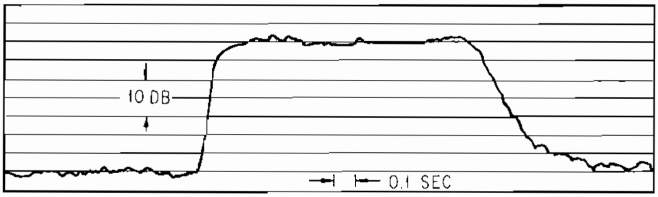


FIG. 1-29. Growth and decay curve of vibrating convex panel.

This absorption characteristic in conjunction with its dispersing action makes convex wood paneling ideal for small studios.

Objectionable Shapes—Interference Phenomena

Flat, untreated surfaces, if very extended in area or if close to the recording microphone, may give rise to objectionable interferences due to the phase difference between the direct and reflected sounds. The "loud" and "dead' spots caused at various frequencies when the direct and reflected waves are comparable in intensity level can become very pronounced and, owing to frequency discrimination, give a hollow-sounding effect. In view of this effect it is desirable that all flat surfaces in the studio have some absorption or else be shaped to disperse the reflection.

Concavely curved surfaces, even though treated with absorbing material, should be avoided. Because of their focusing effect, such surfaces accentuate the interference problems already discussed.

In larger rooms, reflections from concave surfaces and from large untreated flat areas give further trouble due to the echo or time-delay effect and therefore should definitely be avoided.

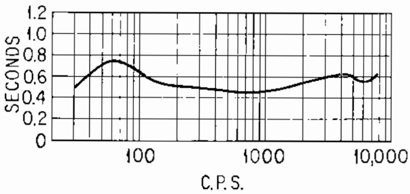


FIG. 1-30. Reverberation time of listening studio.

Studio with Polycylindrical Wood Panels

In addition to the cylindrical wood diffusers already mentioned, such studios have several other features of interest in room acoustic design.

In order to obtain maximum diffusion in three orthogonal planes, axes of the polycylindrical surfaces are placed mutually perpendicular to each other. Three different-sized panels and curvatures are used further to obtain asymmetry in the pattern of diffused sound. The high degree of diffusion obtained in this type of room is evidenced in the smoothness of decay curves. The reverberation curve for one such studio is shown in Fig. 1-30, which conforms reasonably well with published optimal times.

Another feature of the reference studio is the choice of the major dimensions (12.5 by 20 by 32 ft) which progress in two-third octave steps in order to avoid the "piling up" of room resonances. This is especially important as already pointed out for small rooms where the frequency gap between fundamental and harmonic resonances is oftentimes great and unless guarded against may lead to a room response with wide hollows in the audible range. In the present case this consideration was important because the use of large convex diffusers effective in the range below approximately 300 cps was not considered practical. In large rooms consideration should be given to the use of low-frequency diffusers as well as for the mid-range and high frequencies.

Orchestra Shell

Occasionally regular sound stages (usually treated over the entire wall area with 4-in. rock wool and over the entire ceiling area with 2-ft rock wool to eliminate all reflections) are employed for musical recordings, in which case it is necessary to "liven" the stage.

In an application of polycylindrical design to an orchestra shell the multiplicity of dispersing surfaces and resonant panels not only minimizes the microphone placement problem but gives a more pleasing reinforcement of sound to the conductor and musicians. The platforms can be used for elevating and reinforcing the bass instruments in the orchestra.

Exclusion of Noise

A review room with good acoustics has its walls insulated against the transmission of outside noises into the studio. The transmission of sound is of two kinds: (1) aerial and (2) structural. Small openings due to doors, windows, portholes, etc., transmit sound to a great degree. Thus, all the joints between walls, doors, windows, etc., should be made as airtight as possible.

Likewise, transmission of sound through structures, such as the noise from vibrating motors and machinery, should be minimized by using massive walls and floors and by separating all vibrating bodies from their supporting structures by sound-insulating materials such as cork, lead, or rubber.

Massive walls are not always necessary to obtain sufficient sound insulation. A double wall of fairly light construction will give good sound insulation provided the two walls are not closely coupled mechanically by nails or cross members, that is, provided the walls are kept isolated or separated from each other.

Projection Booth

Treating of ceilings and walls inside the projection booth lowers the noise level, permitting more accurate control of volume and quality.

Treating ceilings and walls by lowering the noise level reduces the sound transmitted into the studio. Insulation of machines from the floor by heavy blocks mounted on cork or Keldur is often necessary to reduce transmitted sound.

Double or triple optical glass in ports is generally used to reduce the sound conducted by the air through these ports.

The projection booth walls either should be very heavy (12-in. brick walls) or should be constructed with double walls which are isolated from each other so as not to conduct sound by supporting them on some such material as felt and avoiding any construction which will tie the walls rigidly together.

Figure 1-31 shows a cross section of a typical projection-booth window of the sound-retarding type in accordance with principles outlined by National Broadcasting Company engineers and others. Figure 1-32 shows a cross section of a typical sound-retarding door such as the Riverbank door used by broadcasting stations and other sound studios. Figure 1-33 illustrates construction of a typical sound-insulating wall in accordance with principles stated by Bagenal and Wood in their book "Planning for Good Acoustics."

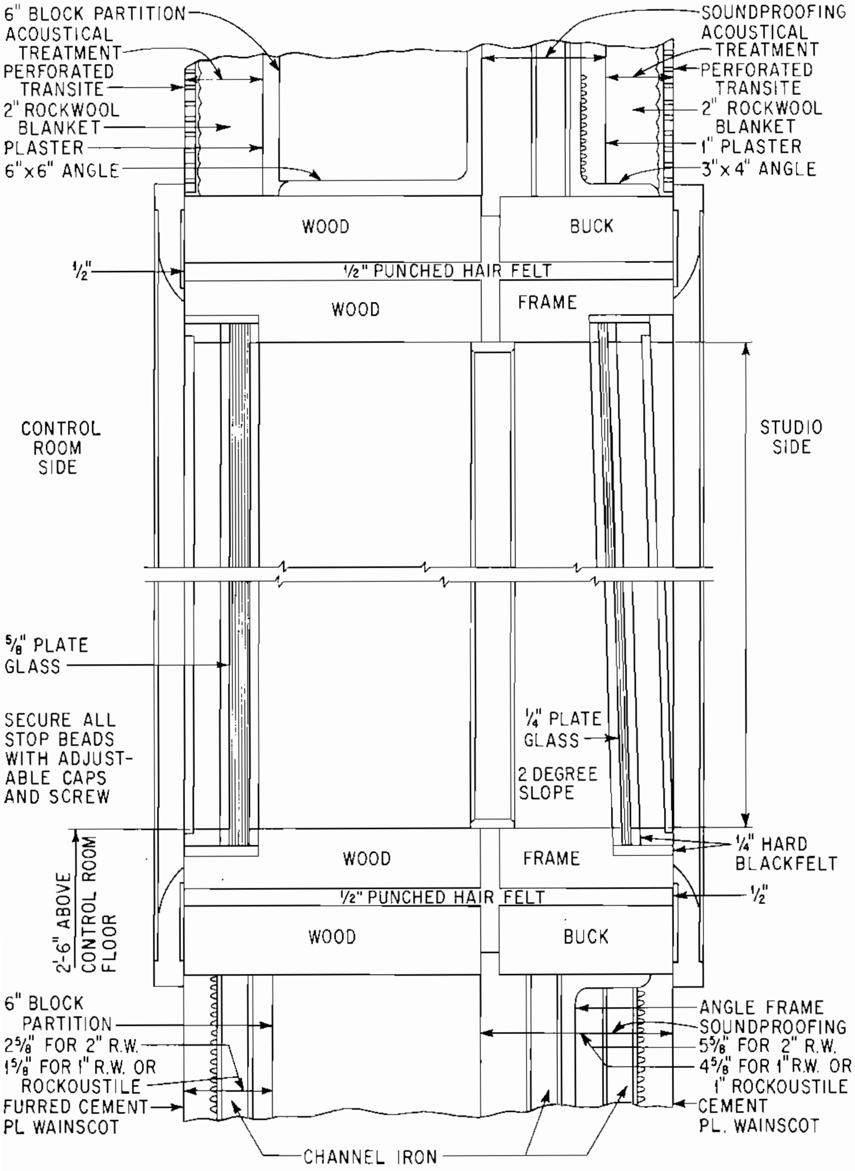


FIG. 1-31. Sound-insulated window.

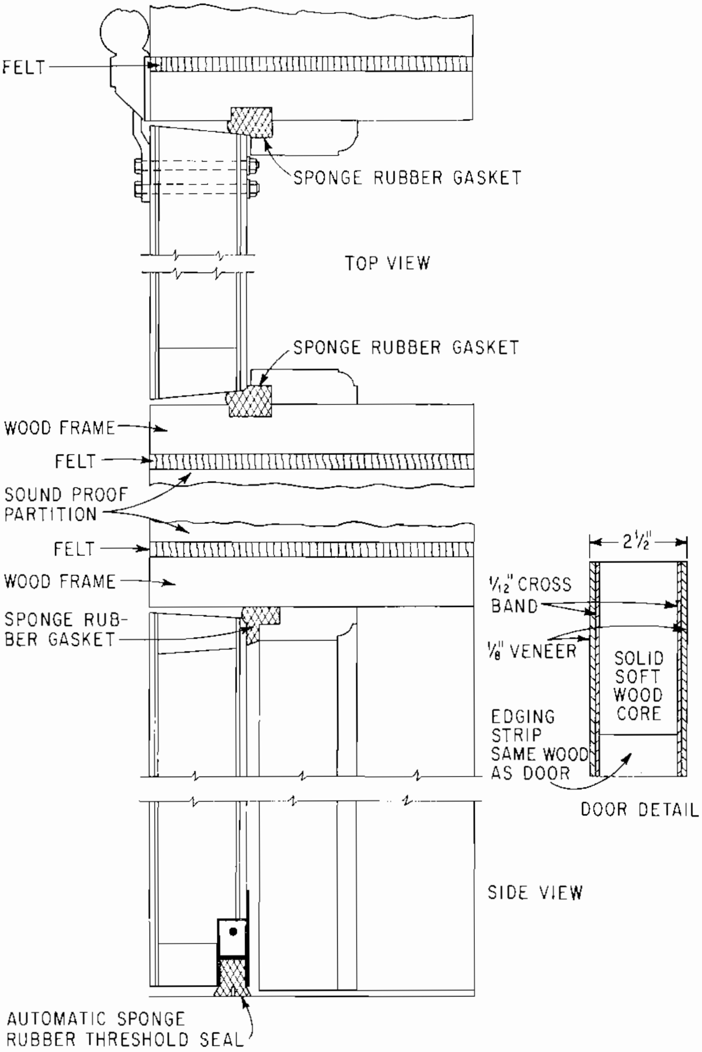


Fig. 1-32. Sound-retarding door.

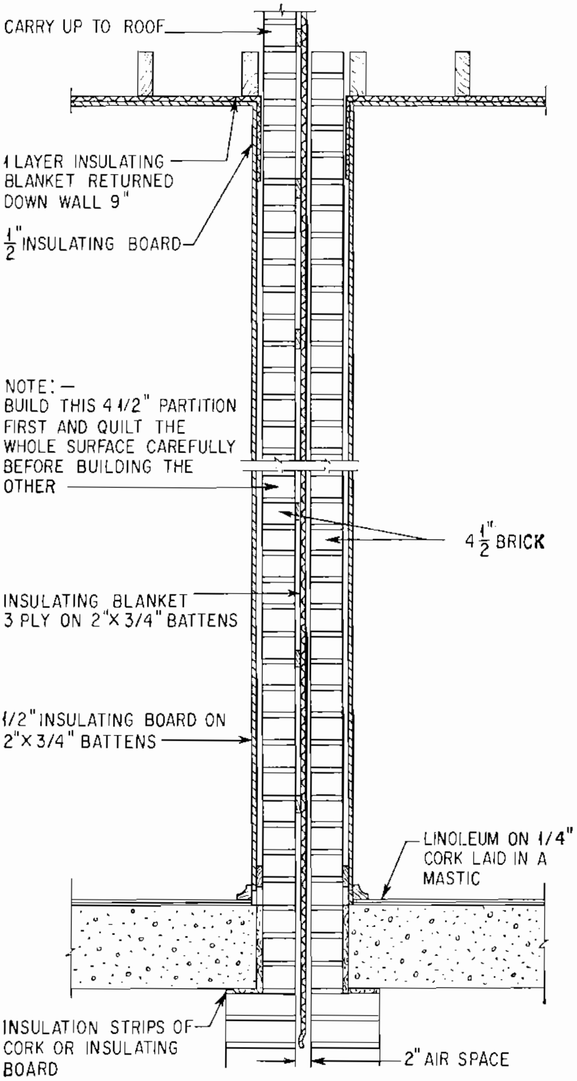


Fig. 1-33. Sound-insulating wall construction.

Acoustic Design of a Typical Small Combination Studio

The following specification covers, in accordance with the principles already outlined, recommendations on the acoustic treatment of a typical small combination studio.

Purpose of Studio

The general purpose of this studio is to provide the following recording functions:

1. Straight recording (voice or music)
2. Pre- or postscoring of small orchestras
3. Rerecording
4. Reviewing and projection
5. Monitoring and control

A plan view showing the general arrangement of rooms and equipment to serve these functions is given in Fig. 1-34.

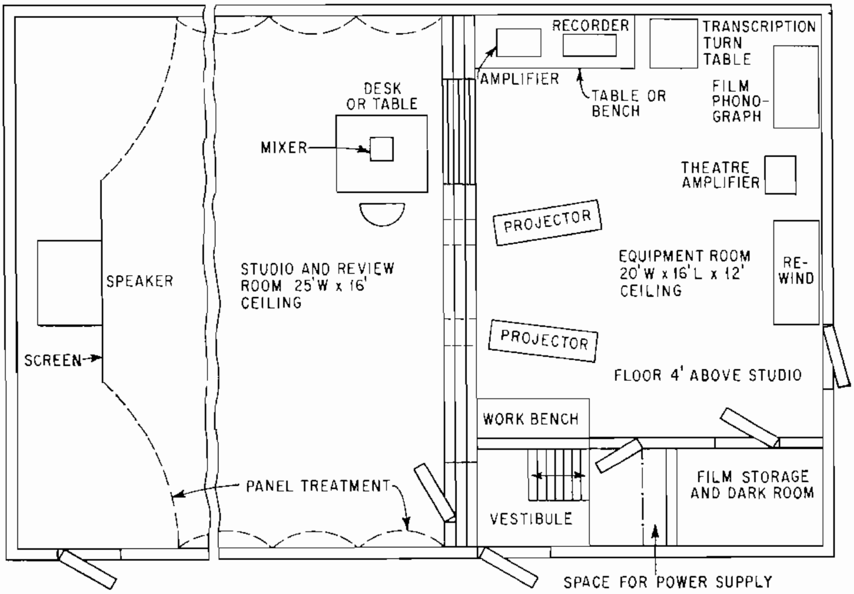


FIG. 1-34. Proposed arrangement of a small studio.

Size and Proportions of Studio

The studio proper shall have a minimum volume of 16,000 cu ft and shall have its average height, width, and length proportioned in the ratio of 1 to 1.6 to 2.5, namely,

Height, 16 ft
Width, 25 ft
Length, 40 ft

A deviation in average dimension not greater than plus or minus five per cent is permissible (see Fig. 1-23).

It should be noted that this studio constitutes the very minimum requirements commercially acceptable with regard to size and will produce optimum results for orchestras of 10 pieces or less. When larger size orchestras are contemplated, the minimum requirements of 50,000 to 65,000 cu ft (25 by 40 by 65 ft) as practiced in Hollywood should be adhered to.

Shape of Studio

The general shape of the studio shall be such that all reflecting surfaces in the room shall be convexly curved to disperse the sound in random directions. The proposed design with polycylindrical surfaces shown in Fig. 1-35 is recommended for this purpose.

Walls

All walls shall be treated with convex wood panels, general specifications for which are given in Fig. 1-25. The panels on the rear wall should be disposed horizontally, while the front and side-wall panels should be vertical as indicated in Fig. 1-35. All walls shall be insulated as specified later. Double-wall construction is particularly important between the projection booth and studio. A blanket of 1-in rock wool or other sound-absorbing material should line the entire back of the wood paneling.

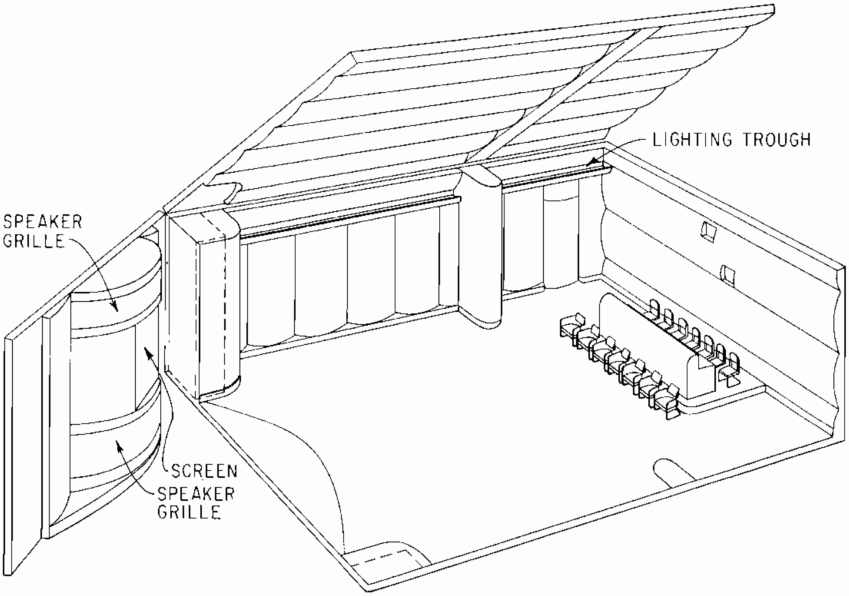


FIG. 1-35. Proposed design of a small film-recording studio and review room.

Ceiling

The entire ceiling shall be treated with convex wood panels which are disposed lengthwise to the room as shown in Fig. 1-35. The attic side of the ceiling should receive a granulated fill of rock wool or similar acoustical material to "load" the ceiling and to afford partial sound insulation against external noises.

Floor

The entire floor area (except in orchestra or band-shell area) should be covered with a good grade of reinforced carpeting with padding underneath. All seats should be of the heavily upholstered type.

Loudspeaker Chamber and Screen

The loudspeaker preferably should be mounted flush with the screen wall, and all openings between them caulked to give a sealtight chamber. The ceiling and back side of the screen wall forming the loudspeaker chamber should be lined with 4 in. of rock wool.

Sound-absorption Treatment

No additional absorption is required for reviewing and scoring purposes to that provided inherently by the wood paneling and floor treatment. For dialogue recording it is desirable to furnish adjustable draperies on any nearby wall in the microphone area.

Exclusion of External Noise and Building Vibration

A noise survey of the proposed studio site should be made by a qualified acoustical engineer before plans are drawn. From the viewpoint of excluding outside noises and building vibrations it is essential that during erection all joints and openings between panels, etc., shall be fully caulked to give a continuous and sealtight enclosure and furthermore that the entire wall structure shall be floated on cork, rubber, or other suitable material in order to isolate the walls completely from the main building structure. This precaution is extremely important, since a single mechanical bridge or solid connection between the inner and outer shells caused by nails, pipes, ducts, etc., can almost completely nullify the sound insulation by setting the inner structure into vibration. Any bracing between inner and outer walls which may be necessary for structural reasons should receive individual isolation treatment to break the continuous mechanical connection. The various methods employed in building practice and patented methods for vibration isolation are too numerous to treat in these specifications. The underlying principle for preventing transmission through solids is to avoid a continuous medium (reinforced concrete, brick, etc.) or solid connection (wood, metal, etc.) by interposing a resilient or less dense material (cork, rubber, felt, air, etc.) in the link between the source of vibration and the reception point. In general the greater the number of such discontinuities (dense to less dense medium and vice versa), the greater the isolation effect. The ceiling and floor structure should receive similar caulking and vibration-isolation treatment.

Exclusion of Air-borne Noises—Ventilation Ducts

In addition to caulking all openings around pipes, ducts, etc., entering the studio with a mastic felt or other soft material, it is essential to line all ventilator ducts on the inside with an efficient sound-absorbing material and on the outside with a sound deadener for a sufficient distance from the point where they enter the studio so that the ambient noise level in the studio is not greater than 30 db above the standard reference level of 10^{-16} acoustic watt per square centimeter, using a noise-level meter set on the 30-db loudness contour characteristic. In general this represents a distance equal to at least ten times the duct diameter. Extra precaution should be taken at the point where the duct enters the studio that outside noise does not leak through owing to the canvas or other isolation coupling.

Recording and Projection Booth

The size of the projection and recording equipment booth should be 20 by 16 ft with a 12-ft ceiling height as indicated in the floor plan in Fig. 1-34. The booth floor should be elevated 4 ft above the studio floor level and should be properly insulated according to the principles already outlined. (Either the entire booth floor or the areas under all vibrating equipment or both should be isolated from direct connections to the main building structure with 1-in. felted asphalt mastic.)

The ceiling and exposed wall areas above wainscot level should be treated with a fireproof sound absorbent.

Vestibule

Entrance to the studio should be made only through double sound-insulating doors or a sound lock. Details of a typical sound-insulating door are shown in Fig. 1-32. The vestibule or sound-lock area can be used for storage or other non-noise-producing purposes as shown in the proposed studio floor plan.

Summary

Acoustic Treatment Guide

The main design features and considerations essential to good acoustics in small studios can be summarized as follows:

1. The size of the studio should be commensurate with the number and kind of musical instruments to be recorded. For a 10-piece orchestra the minimum volume would be 16,000 cu ft. (For orchestras of other sizes refer to Table 1-4.)
2. The major dimensions of the studio should be proportioned to give a preferred ratio of average height, width, and length of 1 to 1.6 to 2.5. For a volume of 16,000 cu ft this would represent a studio 16 by 25 by 40 ft.
3. Large parallel surfaces should be avoided.
4. All reflecting surfaces should be shaped, preferably convex, to give a diffuse distribution of sound and to minimize the effects of standing-wave resonances.
5. If polycylindrical surfaces are used, their size and shape should be varied and their axes disposed to be mutually perpendicular in the three orthogonal planes.
6. The characteristics of convex wood paneling are particularly well suited for supplying the necessary absorption and diffusing properties for studios. The panel bracings should be spaced at random distances to avoid selective resonance. The panels should be varied in size, and backs lined with rock wool or other absorbing blanket.
7. The floor should be covered with a good grade of reinforced carpeting with padding underneath.
8. Seats should be of the upholstered type.
9. Adjustable draperies should be provided on wall surfaces in the microphone area for speech recordings.
10. Studio walls, ceiling, and floor should possess sufficient sound isolation to prevent the transmission of extraneous noises into the studio.
11. The projection booth should be treated with a fireproof sound absorbent on ceiling and exposed wall areas above wainscot level.
12. All machinery and vibrating equipment such as arc generators, voltage regulators, ventilators, etc., should be acoustically isolated from the studio.
13. Air-conditioning equipment should be of the low-velocity type and preferably operated to give full volume at half speed. All ducts should be provided with acoustic baffling and lined for a distance of at least 10 diameters from the studio.

The foregoing general recommendations on the acoustic treatment for studios are offered merely as a guide. The services of a qualified acoustic engineer should be relied upon for the exact specifications relative to the proper type, amount and location of acoustic treatment, shape of studio, and type and amount of sound insulation required. The trend today is toward close cooperation between architect and engineer and toward functional styling based on the acoustic design. In the case of new studios, a noise survey of the proposed site and complete acoustic specifications for the studio are desirable and worth while.

In illustrations or references to acoustical insulating materials in this book, specific materials mentioned are listed only as an example of a material suitable for the purpose described. Any equivalent acoustical material can be used with similar results.

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Appendix A

Definitions in Architectural Acoustics from ASA Standards Z24.1

ACOUSTIC ABSORPTIVITY (ABSORPTION COEFFICIENT): The acoustic absorptivity of a surface is equal to 1 minus the reflectivity of that surface.

ACOUSTIC REFLECTIVITY (REFLECTION COEFFICIENT): The acoustic reflectivity of a surface not a generator is the ratio of the rate of flow of sound energy reflected from the surface, on the side of incidence, to the incident rate of flow. Unless otherwise specified, all possible directions of incident flow are assumed to be equally probable. Also, unless otherwise stated, the values given apply to a portion of an infinite surface, thus eliminating edge effects.

ACOUSTIC TRANSMITTIVITY: The acoustic transmittivity of an interface or septum is the ratio of the rate of flow of transmitted sound energy to the rate of incident flow. Unless otherwise specified, all directions of incident flow are assumed to be equally probable.

CYCLE (~): One complete set of the recurrent values of a periodic quantity comprises a cycle.

DIFFUSE SOUND: Sound is said to be in a perfectly diffuse state when, in the region considered, the energy density, averaged over portions of the region large compared with the wavelength, is uniform and when all directions of energy flux at all parts of the region are equally probable.

ECHO: An echo is a wave which has been reflected or otherwise returned with sufficient magnitude and delay to be perceived in some manner as a wave distinct from that directly transmitted.

FLUTTER ECHO: A flutter echo is a rapid succession of reflected pulses resulting from a single initial pulse. If the flutter echo is periodic and if the frequency is in the audible range, it is called a musical echo.

FREQUENCY (f): The number of cycles occurring per unit of time or which would occur per unit of time if all subsequent cycles were identical with the cycle under consideration is the frequency. The frequency is the reciprocal of the period. The unit is the cycle per second.

INTENSITY LEVEL (IL) (SOUND ENERGY FLUX DENSITY LEVEL): The intensity level, in bels, of a sound is the logarithm to the base 10 of the ratio of the intensity I of this sound to the reference intensity I_0. Intensity level can also be expressed in decibels.

INTERFERENCE PATTERN: An interference pattern is the resulting space distribution of pressure, particle velocity, energy density, or energy flux when sound waves of the same frequency are superposed.

MEAN FREE PATH: The mean free path for sound waves in an enclosure is the average distance sound travels in the enclosure between successive reflections.

Multiple Echo: A multiple echo is a succession of separately distinguishable echoes from a single source.

Noise: Noise is any undesired sound.

Rate of Decay (of Sound Energy Density) (S): The rate of decay of sound energy density is the time rate at which the sound energy density is decreasing at a given point and at a given time. The practical unit is the decibel per second.

Reverberation: Reverberation is the persistence of sound due to repeated reflections.

Reverberation Time (T): The reverberation time for a given frequency is the time required for the average sound energy density, initially in a steady state, to decrease after the source is stopped to one-millionth of its initial value. The unit is the second.

Sabin: The sabin is a unit of equivalent absorption and is equal to the equivalent absorption of one square foot of a surface of unit absorptivity, i.e., of one square foot of surface which absorbs all incident sound energy.

Sound: (1) Sound is an alteration in pressure, particle displacement, or particle velocity propagated in an elastic material or the superposition of such propagated alterations. (2) Sound is also the sensation produced through the ear by the alterations described above.

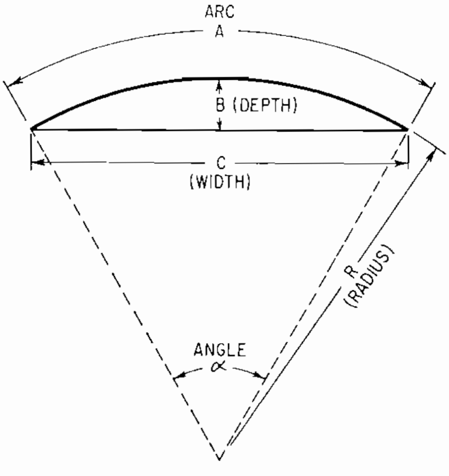
Note: In case of possible confusion, the term *sound wave* can be used for concept (1) and the term *sound sensation* for concept (2).

Wavelength (λ): The wavelength of a periodic wave in an isotropic medium is the perpendicular distance between two wavefronts in which the displacements have a phase difference of one complete cycle.

Appendix B

Sectional Dimensions in Inches for Convex Cylindrical Panels

α	60°			90°			120°			180°
Arc (a)	Width (c)	Depth (b)	Radius (r)	Width (c)	Depth (b)	Radius (r)	Width (c)	Depth (b)	Radius (r)	Radius (r)
16	15¼	2	15¼	14⅜	3	10⅜	13⅛	3⅞	7⅝	5⅛
32	30⅝	4⅛	30⅝	28¾	6	20¾	26¼	7⅝	15¼	10⅛
48	45⅞	6⅛	45⅞	43¼	9	31¼	39½	11½	22⅞	15¼
64	61⅛	8¼	61⅛	57⅝	12	41⅝	52⅝	15¼	30½	20⅜
80	76⅜	10¼	76⅜	72	15	52	65¾	19⅛	38⅛	25½
96	91⅝	12¼	91⅝	86⅜	18	62⅜	78⅞	23	45¾	30½
112	107	14⅜	107	100¾	21	72¾	92⅛	26¾	53⅜	35⅝
128	122¼	16⅜	122¼	115¼	23⅞	83¼	105¼	30⅝	61	40¾
144	137½	18⅜	137½	129⅝	26⅞	93⅝	118⅜	34⅜	68⅝	45¾



LIVENESS IN BROADCASTING *

When your friend tells you the news, do you prefer to have him sit comfortably in your home with you or to talk at you from a box? When you attend a concert, do you prefer to be in the audience and hear the sweep of the music through the hall or to have the sound shot at you from a cabinet? Your radio can now bring your favorite newscaster, in living reality, to your home or can transport you to the best seats in the concert hall. This article tells you how it is done.

Under normal conditions, you listen to an orchestra, to a singer, or perhaps to someone telling you the latest news with two ears. The binaural sense which results from the use of the two ears enables you to pay attention to the sound arriving from any desired direction and partially to exclude the sound from other directions. Similarly, you easily separate nearby sounds from the more distant ones. You have, therefore, two means of accentuating, at will, certain parts of the sound.

If, however, the sound has been picked up by one or more microphones and reproduced through a single loudspeaker, your binaural ability to pay attention to the sound from any desired direction is completely lost. This results in an apparent increase in the "liveness," or reverberation, present and also in the intensity of the incidental noises. However, your ability to distinguish between nearby and distant sounds is in no way impaired but is frequently enhanced.

Therefore, the situation can be summarized as follows:

1. You have lost all ability to accentuate at will certain parts of the sound, such as solo artist, by the help of the direction from which that particular sound comes.
2. You still maintain your ability to accentuate by the distinction between nearby and distant sounds.
3. The liveness, i.e., the apparent amount of reverberation, has been automatically accentuated.

Any studio technique which is to reproduce lifelike and realistic programs must (1) provide the studio engineer with a means of supplying the necessary accentuation lost by the failure of the binaural sense, (2) provide the engineer with means of making full use of the distinction between nearby and distant sounds, (3) eliminate the undesired accentuation of the apparent liveness.

This is particularly true, as the sense of realism experienced by the listener is as much dependent on the microphone placement and the studio acoustics as it is on his home conditions.

Greater Coverage

The purpose of this article is to describe a technique of studio and auditorium sound pickup which fulfills the above requirements and which places control of the desired accentuations on the dials of the studio mixer panel. Fortunately, the correction for the increased apparent reverberation can be accomplished by the initial placement of the microphones used.

One of the important advantages of this live type of pickup is as much as 6-db gain in coverage at no extra expense to the sponsor or the broadcasting company.

This unexpected gain is a result of the manner in which the ears of the listener perform. For a given power supplied to the loudspeaker, the loudness of a program picked up with this new technique can be 6 to 8 db greater than the loudness of programs from "dead" pickups. Since this gain in loudness permits the listener to operate his receiving set with a correspondingly lower electrical gain, static and other noises are reduced by this amount. Thus, this effect is a real gain in coverage.

In view of this apparently complicated situation, a search was made for some simple acoustic constant which would clarify the studio problems. Such a constant has been derived mathematically and checked by practical application to studio practice.

This constant is called *liveness* and represents the acoustic properties of an enclosed

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space, such as a studio or auditorium, including the effect of the distances from the artists to the pickup microphones. The properties of this constant are such that the formula can be readily applied to the use of one general, or "over-all," microphone in combination with the necessary additional microphones for accentuation purposes.

The liveness formula is

$$L = \frac{1{,}000T^2D^2}{G_pV} \qquad (1\text{-}1)$$

where L = liveness
T = reverberation time, sec
D = distance from sound to microphone, ft
V = volume of studio, cu ft
G_p = directivity of pickup microphone from source to microphone

The value of T used for the practical application of this technique to broadcast pickup is an average of the values over the frequency range from 500 to 2,000 cps. Where this average is unknown, the value at 1,000 or even 500 cps can be used as a guide.

The range of the limits of liveness for satisfactory binaural listening is very great but is quite narrow for monaural, or single-channel, reproduction. However, experience has shown that with single-mike pickup the limits of the value of liveness selected for best monaural pickup always lie within those acceptable for direct listening. This means that in the concert hall, for example, the microphone position is always farther from the sound source than the front row of acceptable seats but nearer to the sound source than the rear row. The center of the monaural range is always closer to the source than that position generally rated as best for direct listening. This increased closeness of the monaural microphone automatically removes the accentuation of the apparent excess reverberation present.

The full useful range of liveness for monaural pickup varies materially from one type of sound to another as, for instance, from symphony orchestra to solo singing to speech. Table 1-5 shows the values of the monaural liveness range for several different types of sound when picked up for reproduction in average living rooms. It may be of interest to know that where the reproducing space is abnormally live, both limits of the useful range are moved upward, not downward. Where the listening space is abnormally dead, the values must be decreased accordingly.

Table 1-5

Type of sound	*Liveness range*
Piano	4–16
Symphony orchestra	5–20
Small orchestra	3–12
Solo violin, cello, etc.	1–4
Solo singing	½–3
Speech	⅙–⅔

Increased Sense of Reality

If sound is reproduced from a pickup in which the liveness is controlled within the useful range as shown in Table 1-5, the subjective effect might be described as the acoustic recreation of the pickup space around and behind the loudspeaker position. This effect adds greatly to a sense of reality and renders music or speech both natural and "easy to listen to." Under these circumstances, it is difficult to locate the position of the loudspeaker laterally, the sound appearing to flood in from behind it through an opening completely across the room. In other words, the effect is that of adding the studio space behind the plane of the loudspeaker without any intervening wall.

When the liveness is near the lower limit of the useful range, you get the impression that the sound is situated in the near end of this added space. In the case of a person speaking, there is the illusion of a real person speaking from the position of the loudspeaker.

When, however, the liveness is near the upper limit of the useful range, the source of sound appears to be considerably behind the plane of the loudspeaker as if it were coming to the hearer from a position in the remote end of the added space. In the case of broadcasting large symphony orchestras, this control of liveness enables one so to broadcast a concert that the listener in his home may seem to occupy any seat from the front to the back row of the auditorium. Since most auditoria have seats which music critics consider to be best, it is desirable to control the liveness of the broadcast so that the listeners are placed acoustically in that portion of the auditorium.

When pickups are made with a liveness value well below the useful range, this effect of added space disappears and one is aware of the sound being projected from the box containing the loudspeaker. Under these conditions, it has an artificial quality which could never be mistaken for the presence of a real person or a real orchestra. This effect might be called "absence" as opposed to the much desired "presence" of good broadcast pickup.

Under these dead conditions, the lateral position of the loudspeaker can be accurately located by ear and the interpretation of quality is quite sensitive to one's position with respect to the high-frequency beam of the loudspeaker and to the volume at which the sound is being reproduced.

On the other hand, when the liveness value is well above the upper limit of the useful range, one can again locate with ease the position of the loudspeaker. However, instead of feeling that the sound is being projected from a point source, the hearer experiences the effect of the sound reaching him through an open window from a room which is much more reverberant than the one in which he is listening.

Considerable evidence has been obtained that the public much prefers recordings made well within the useful range and in the case of orchestral music near its upper limit.

The advantages of this type of pickup can be summarized as follows:

1. The 6-db gain in coverage previously mentioned.
2. When operating within the useful liveness range, the amount of manual volume control normally necessary with dead pickup is markedly decreased without either overloading the equipment or causing the sound to sink into background noise and therefore permits a higher average per cent modulation.
3. For a given volume range as indicated by the VU meter, reproductions from monaural sound pickups made within the useful range have an apparent volume range nearly twice that of similar reproductions from dead pickups.
4. The change in quality of the monaurally reproduced sound as a function of the loudness of reproduction is materially reduced. This characteristic can be best illustrated by two contrasting cases.

Case 1

Assume that the sound from an orchestra, for instance, has been picked up under conditions of liveness well below the useful range and that this sound has been balanced for reproduction at an average intensity level of 75 db at the ear.

If this sound is now reproduced at an average ear level substantially lower than 75 db, marked distortion of the balance takes place. The lower notes and the high harmonics appear to be greatly attenuated. A similar effect in the reverse direction occurs if the sound is reproduced at a level substantially higher than that for which it was balanced. An equalizer introduced into the reproducing circuit will correct this unbalance if its characteristics correspond to the differences in the loudness contours of the Fletcher-Munson curves.

Case 2

Assume that the sound referred to in Case 1 has been picked up under conditions of liveness well within the useful range and, as before, has been balanced for reproduction at an average ear level of 75 db.

If this sound is reproduced at an average ear level either substantially lower or substantially higher than 75 db, very little, if any, apparent change of quality is noticeable. This advantage is of great value to the listening audience, as it enables the listener to reproduce a sound in his living room at any desired level without a corresponding loss of quality.

Two or More Microphones *

The pickup technique being described consists basically of the use of (1) a microphone situated at some distance from the performers to pick up the general blend of sound and (2) one or more accentuation microphones for accenting desired portions of the orchestra, soloists, etc. This accentuation is obtained by controlling the liveness instead of the loudness.

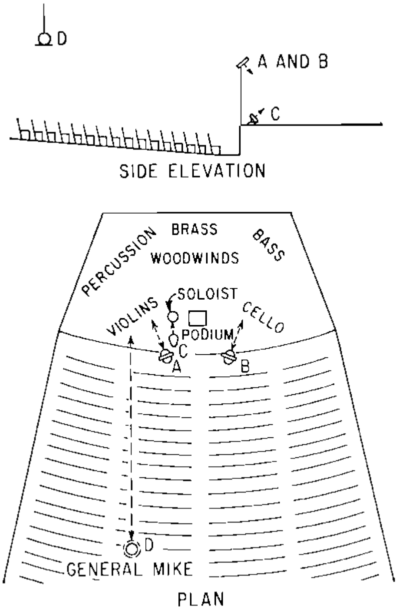

FIG. 1-36. Large auditorium with a symphony orchestra. *A* and *B*, accentuation microphones; *C*, solo microphone; *D*, general microphone. Dotted lines show distances which can be computed as described elsewhere.

The general microphone preferably has nondirectional characteristics as typified by the Western Electric 640AA or the 633 type. The accentuation microphones are usually of the bidirectional or of the cardioid type typified by the Western Electric 639 type. Any high-quality microphone, having the proper characteristics, will operate in an entirely satisfactory manner.

Figure 1-36 shows a qualitative arrangement for a symphonic broadcast with soloist

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* The manufacture of the Western Electric microphones mentioned in this article has been discontinued.

and some orchestral accentuation, while Fig. 1-37 shows a typical studio setup for orchestra with vocals. It should be realized, of course, that all the accentuation microphones are not necessarily used simultaneously.

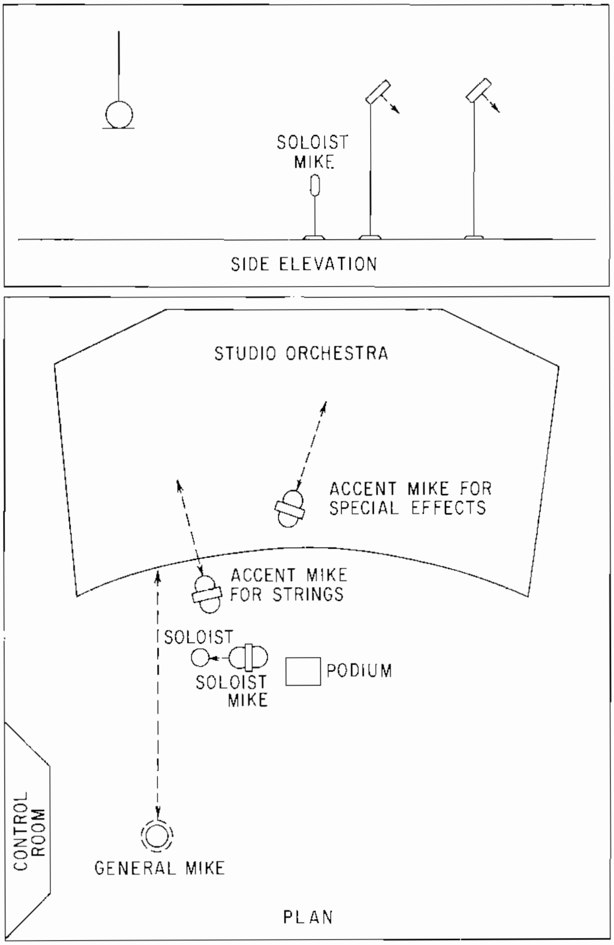

FIG. 1-37. Plan and side elevation of normal studio set up for orchestra with vocals. It should be noted that all the accentuation microphones in this arrangement are not necessarily used at the same time.

Arrangements such as these ensure the fulfillment of the following requirements:

1. Over-all liveness control is available to the sound engineer at all times during the broadcast.
2. Accentuation control is similarly available at all times.
3. The loss, by failure, of any one microphone does not render the pickup unsuitable for broadcast.
4. The arrangement is versatile and capable of rapid adjustment during rehearsal.

The employment of this technique requires studios with acoustic properties of a "pleasing" nature, i.e., studios of good acoustic properties. It also requires that studios shall not be overcrowded.

Figure 1-38 shows the relation between the number of artists and the studio size. Curve *A* represents good studio practice, while curve *B* represents the maximum crowding possible without loss of realism. Curve *C* is given for comparison only and represents auditorium conditions for symphonic music.

Figure 1-39 shows the optimum reverberation time with artists in place, as a function of studio or auditorium size. Any values within 30 per cent of those shown can be compensated for by a proper choice of microphone positions.

Placement and Control of Microphones

Positioning the General, or Over-all, Microphone

1. Choose from Table 1-5 the maximum value of liveness necessary for any part of the program. For instance, for a studio pickup of a dance orchestra with vocals the maximum value of L is 12 for small orchestra.

2. Choose a value 1.5 times this ($L = 18$) as suitable for the over-all microphone. The increase of one and one-half is to allow you margin for leaving some accentuation microphones in circuit at all times without reducing the general liveness too much.

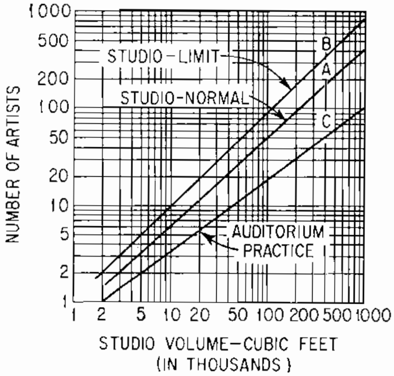

FIG. 1-38. Relation between number of artists and studio size. *A* shows good studio practice; *B*, maximum crowding without loss of realism; *C*, for comparison, shows auditorium conditions for symphonic music.

3. Determine the distance D from Eq. (1-2) below. D represents the distance of the microphones from the front of the orchestra.

Equation (1-1) can be solved for D and we get

$$D = \frac{\sqrt{LVG_p}}{31.6T} \tag{1-2}$$

Where studios are in active use, a set of curves as shown in Fig. 1-40 can be prepared. To aid you in preparing such a chart the following typical case is worked out in detail.

Assume a studio whose volume V is 30,000 cu ft and whose reverberation time T, with musicians in place, is 1.2 sec. For nondirectional microphones $G_p = 1$, and for bidirectional or cardioid type $G_p = 3$ for sound sources on their beams. Assume a range of L from 0.3 to 30.

From Eq. (1-2) for a nondirectional microphone we get

$$D = \frac{\sqrt{30 \times 30{,}000 \times 1.0}}{31.6 \times 1.2} = 24.6 \text{ ft for } L = 30$$

Similarly $D = 2.46$ ft for $L = 0.3$.

Plot these two points (A and B of Fig. 1-40) and connect them with a straight line. From this chart the distance D corresponding to any desired value of liveness can be obtained for a nondirectional microphone.

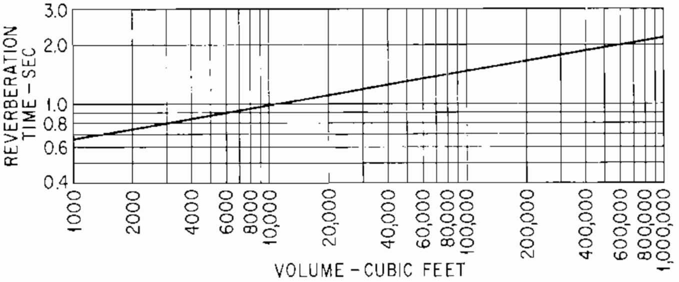

FIG. 1-39. Curve showing optimum reverberation time with artists in place as a function of studio or auditorium size. Any values within 30 per cent of above can be compensated for by microphone placement.

To obtain the plot for bidirectional or cardioid microphones proceed in a similar manner letting $G_p = 3$. Then we obtain the points M and N, Fig. 1-40. Connect these with a straight line.

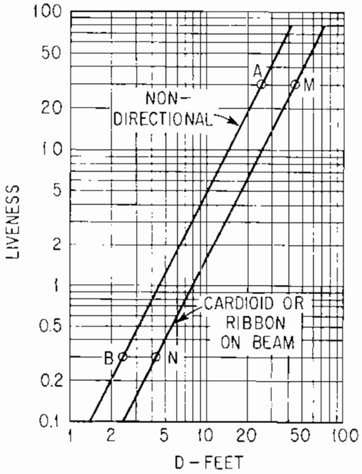

FIG. 1-40. Typical chart used for positioning general and accentuation microphones in active studios.

This completed chart is now available for use in positioning the general microphone and, as described in the next section, for positioning the accentuation microphones also.

Positioning the Accentuation Microphones

1. Choose from Table 1-5 the minimum liveness for the portion of the orchestra, the soloist, or other course to be accentuated. For instance, for solo parts in the string section choose $L = 1.0$ (solo violin, etc.) or for a vocalist choose $L = \frac{1}{2}$ (solo singing).

2. Choose a value which is two-thirds of that obtained from Table 1-5 as the practical operating liveness for the accentuation microphone. This decrease to two-thirds

is to allow you margin for the increase in liveness due to the over-all microphone, which is always in circuit.

3. Choose a suitable type of microphone—cardioid, bidirection, or nondirectional. One of the directional types is usually preferred as the accentuation microphone, since it can be "beamed," i.e., partially limited to the sound sources on or adjacent to the high-sensitivity axis.

4. Determine the distance D from Eq. (1-2) or from the studio chart typified by Fig. 1-40. If you are using this microphone for accentuation of the string section or any other group of artists, D represents the distance from the microphone to the nearest artist in that group.

5. Proceed in a similar manner for any other accentuation microphones which may be necessary.

Determination of Approximate Mixer Dial Settings

No hard-and-fast rules can be given for control of the amount of accentuation necessary. This amount depends upon the type of program and upon the nature of the esthetic or dramatic illusion you are trying to create for the listener.

However, there are some general considerations which will help you acquire experience more rapidly than is possible with mere "cut-and-try" methods. In the first place, make it a rule to start your rehearsal with the general microphone only—all others being out of circuit. Then slowly fade in the accentuation microphones until the desired result has been obtained. When in doubt, use less accentuation than appears desirable over your monitor. This is due to the fact that most monitoring rooms are both smaller and acoustically more dead than the average living room.

The details of this mixing technique are described in Appendix A. General adherence to the methods outlined there will result in the production of acceptable programs with very little rehearsal.

Important Applications

There are three broad classes of programs to which this technique has been successfully applied: namely, (1) large concert-hall pickup, such as symphony orchestra, opera, choral singing, etc.; (2) studio music programs with or without vocals; (3) speech only, such as news, lectures, announcements, etc.

The Large-concert-hall Type of Program

The most pleasing broadcast of a symphonic or operatic program is the one which creates for the listener the illusion that he is actually present in the auditorium. That effect is obtained when the liveness of the orchestra, including accentuation of any section such as strings, woodwinds, etc., lies between 8 and 20. A good average value for heavy music is 16, while for light delicate music a value of 10 is often preferable.

If the orchestra is accompanying a soloist, for instance, a violinist, a singer, or a pianist, the liveness value for the soloist should never be less than one-quarter of the orchestral liveness and should preferably be between one-half and one-third. When the one-half of orchestral liveness is used, the soloist is well out in front of the orchestra. As the solo liveness is increased, the voice or solo instrument seems to move back and finally becomes merely an accentuated part of the orchestra itself.

The method of determining the dial settings to obtain these effects will be described in detail in Appendix A. If you will use the quantitative method for setting the dials on your first few rehearsals with this new technique, you will soon find that you easily recognize the desired effects by ear and no longer require the computed values except for an approximate check.

Table 1-6 shows the liveness value for each of the three microphones and the power used, expressed in decibels above (+) or below (−) the power supplied by the over-all microphone D, Fig. 1-36.

Table 1-6

Mike	*L*	*Decibels*
D (general)	21	0
A (violin section)	0.6	−18 to −12
B (cello section)	0.6	−18 to −12
C (soloist)	0.5	Not used

The effective liveness of this arrangement is about 13, which value is well within the useful liveness range shown in Table 1-5.

Studio Music Programs with or without Vocals

As before, the most pleasing result is obtained when the listener feels that he is present in the studio. A liveness between 6 and 12 for the orchestra yields this effect. Solo voices should have a value one-half to one-third of the orchestra value, while crooners may operate as low as one-sixth of it. These values are easily obtainable in a good studio which is not overcrowded much beyond curve *B* in Fig. 1-38.

Figure 1-37 shows a typical studio setup. The method of setting the distances and choosing the types of microphone has already been described. However, a sample computation may be helpful.

Assume a 20-piece orchestra and a crooner in a studio crowded to the curve marked *B*, Fig. 1-38. Therefore, the studio volume is about 22,000 cu ft, and it should have a reverberation time of about 1.1 sec (see Fig. 1-39) with orchestra.

Assume that

1. The desired liveness *L* for the orchestra is 10.
2. The desired liveness *L* for the crooner is about 1.6.
3. The general microphone has nondirectional characteristics.
4. The microphone for the crooner and any accentuation microphones for parts of the orchestra have bidirectional characteristics.

Proceed as follows:

1. Set the liveness of the general microphone at a value $1.5 \times 10 = 15$.
2. Set the liveness of the crooner microphone at a liveness not greater than $1.6 \times \frac{2}{3} = 1.0$ approximately. Use 0.5 if in doubt, as slightly more flexibility is assured.
3. Set the orchestral-accentuation microphone at a liveness not greater than $2.0 \times \frac{2}{3} = 1.3$. Use 1.0.

From Eq. (1-2) you get the values in Table 1-7.

Table 1-7

Microphone	*Type*	G_p	*L*	*Distance, ft*
General	Nondirect	1.0	15	16–17
Crooner	Bidirect	3.0	0.5	4–6
Accentuation	Bidirect	3.0	1.0	7–9

If the distance of 4 to 6 ft for the crooner worries you, cut it down to any value not less than 2 ft and mix accordingly (see Appendix A).

Speech Such as Announcers, Newscasters, Lecturers

These programs usually originate in small rooms of 1,000 to 2,000 cu ft with reverberation times of the order of ½ sec.

They get the full benefit of the extra coverage and naturalness due to liveness for values of *L* greater than ⅙ to ¼. From Eq. (1-2) the distance for a nondirectional microphone for a 2,000-cu-ft studio, having a reverberation time of ½ sec, would be 1¼ ft and for a ribbon or cardioid microphone on beam would be 2 ft.

Appendix A. Method of Setting Relative Gain for General and Accentuation Microphones

Let L_a = liveness for accentuation mike
L_g = liveness for general mike
L_e = effective liveness of combination
P_r = ratio of power contributed by accentuation microphone to power contributed by general microphone

then

$$\text{db} = 10 \log P_r$$

It can be shown that

$$P_r = \frac{1 - L_e/L_g}{L_e/L_a - 1} = \frac{L_a L_g - L_e}{L_g L_e - L_a} \tag{1-3}$$

and

$$L_e = \frac{L_a L_g (1 + P_r)}{L_a + P_r L_g} \tag{1-4}$$

For example, if $L_a = 1.0$ and $L_g = 20.0$, we can use Eq. (1-3) and compute the data shown in Table 1-8.

Table 1-8

L_e	P_r	*Decibels*	*Approx. decibels*
1.25	3.75	+5.8	+6
1.50	1.85	+2.7	+3
2.0	0.90	−0.5	0 or −1
3.0	0.43	−3.7	−4
4.0	0.27	−5.7	−6
6.0	0.14	−8.5	−8 or 9
8.0	0.086	−10.7	−10 or 11
12.0	0.036	−14.4	−14
16.0	0.013	−18.8	−19

Where a studio or auditorium is in regular use, it is worth the time to plot this data as a curve. Figure 1-41 shows such a plot.

In Table 1-8 and Fig. 1-41, negative values of decibels mean that the level of the accentuation mike is below that of the general mike by the number of decibels shown.

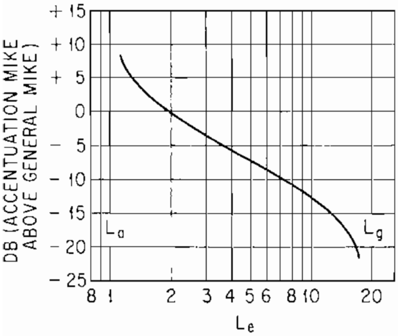

Fig. 1-41. Chart showing effective liveness of two-microphone combination as function of relative level.

Since the sensitivities of the various microphones are not equal, the following procedure must be used to determine this relative gain value.

During rehearsal, set the general microphone attenuator control and master gain control as if the broadcast were to be made on this microphone alone. Read the attenuator dial setting for maximum peaks on the VU meter.

Then turn off the general microphone and turn up the accentuation microphone until the maximum peaks have the same VU reading. Read the attenuator dial for the accentuation mike. This becomes the zero of the decibel scale illustrated in Table 1-8 or in Fig. 1-41.

For example, assume that the general microphone had an attenuator dial setting of 10 db and the accentuation microphone had a dial setting of 14 db for the same maximum peaks as read by the VU meter. This means that with a setting of 14 db the accentuation microphone is contributing the same power as the general microphone.

Then if the desired over-all liveness is 9, we find from Fig. 1-41 that the accentuation microphone should be operated at −12 db. Therefore, the setting would be 26 db on the attenuator dial of the accentuation mike.

It sometimes happens that this low setting of the accentuation microphone causes a blend of the sound which does not seem to have given the accentuation to the desired instruments. This usually indicates that the general mike has been placed in a poor spot and that the accentuation mike is being used to mask this trouble.

Therefore, seek a new location for the general mike as a first step of correction.

Appendix B. Music Programs in Overcrowded Studio

Under these conditions it is usually impossible to place the general microphone at a sufficient distance from the front row of the orchestra. Therefore, a trick must be resorted to.

1. Place a bidirectional microphone, such as 1, Fig. 1-42, with its insensitive direction pointing toward the orchestra. In practice this microphone will act as if G_r [see Eqs. (1-1) and (1-2)] had a value of ¼ to ⅓.
2. Place the necessary accentuation microphones in the standard manner except that bidirectional microphones must not be placed too close to the studio wall. Where the crowding is extreme, the use of cardioid microphones for accentuation purposes is preferred.
3. Use the minimum contribution from the accentuation microphones necessary to obtain the desired effect. Too much accentuation does more damage under overcrowded than under normal conditions and can easily push the pickup into the region below the useful liveness range. You then obtain "absence" instead of "presence."

This discussion has attempted to describe a semiquantitative sound-pickup technique. If it is followed as a general guide, experience has shown that these methods can almost ensure programs with a new realism—programs that can give your station as much as 6-db gain in coverage and your listeners the sense of being in the presence of the living artists.

HOW TO IMPROVE PROGRAM PICKUPS [*]

Make it good. Then make it better. This is the creed of radio engineers. Over a period of 35 years, broadcasting has been made good. Broadcast equipment has reached the state of design where the noise level is negligible and the complete spectrum of audible frequencies is available for transmission and reproduction.

Yet it is apparent to all concerned that the techniques of coordinating and operating this equipment are as confused and almost as varied as the number of stations and the number of operating personnel at each station.

What has not been so apparent is the fact that this situation can spell the success or failure of a well-designed, well-maintained layout. There is extensive literature covering the theory, design, construction, and repair of the equipment, but the importance of using such equipment properly is just beginning to gain recognition of its true worth.

Microphone Facts and Fancies

The microphone is a mechanical extension of the human ear. How often have you heard that one? The fault in this definition lies not so much in its literal meaning as in the implications involved. If it were true, even though you had only one ear, you could walk into a studio and place the microphone at the spot where your one good ear could hear the orchestra, the soloist, the chorus, and the announcer. Only it doesn't work that way in practice. Yet this conception is probably the basic factor in the reasoning of the operator who just sticks up the mike in a studio and

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[*] By Harold E. Ennes, WTAE, Pittsburgh, Pa., from *FM and TV Magazine,* Sleeper Publications, Inc.

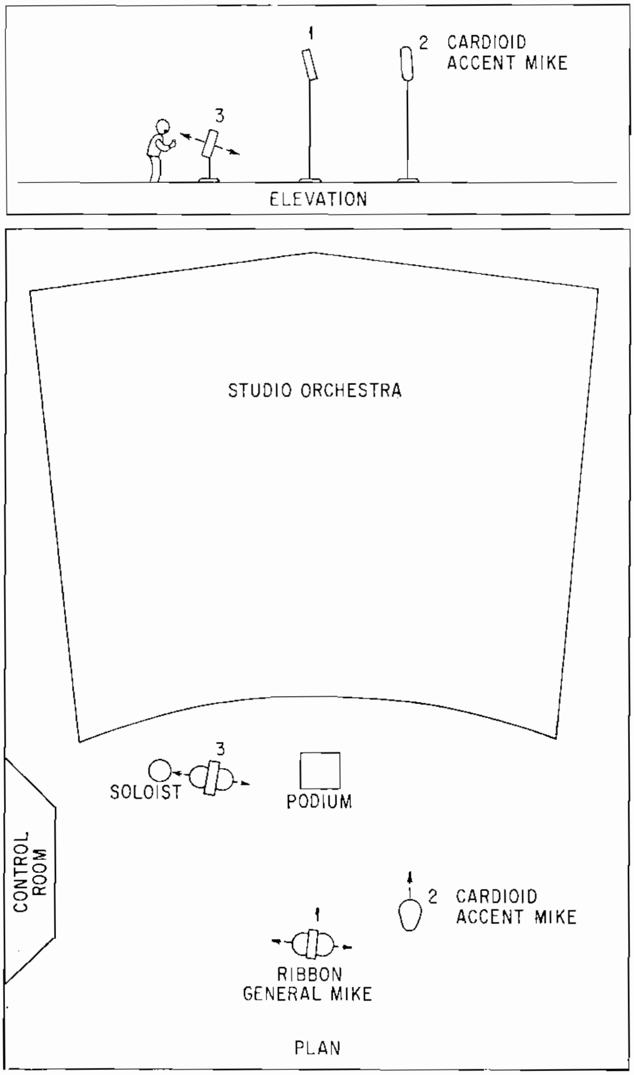


FIG. 1-42. Plan and elevation of overcrowded studio.

proceeds to broadcast the show by riding gain. And there is the more ambitious type who spots a microphone for each section of the orchestra and one for the soloist and announcer and several for the chorus and then becomes very indignant when the conductor reports that his musician friends listened to the show and thought someone else had been on the podium.

To understand why a microphone cannot be considered an extension of the human ear, it is necessary to review the fundamental theory. It is an old story, but absolutely essential to understanding the mike from an operational point of view.

Unlike the human hearing system, which is binaural (two-eared), the microphone is monaural (one-eared). It should be emphasized that this is true regardless of the number of microphones used, since the sound is collected into one channel and reproduced by one loudspeaker while each of our two ears has a separate channel to the brain. Physically, the difference is that in a monaural system the sense of direction is lost while reverberation is somewhat more noticeable, making the apparent distance to the sound source seem greater than when listening binaurally. Any operator who has set up a microphone in a particularly live hall has experienced this phenomenon.

The conversation between two people anywhere in the hall can be heard quite clearly when listening with two ears, but when listening with headphones connected to an amplifier and microphone, the sounds seem much more distant while the extraneous noise is high. This brings up an all-important psychological factor closely linked to the physical effect just explained.

This is the focusing power exerted unconsciously when listening binaurally or even with one ear plugged up as much as is possible. The association of the ear with the nervous system and the brain tends to exclude recognition of the extraneous noise and to focus attention on particular sounds. The microphone, as a mechanical device not associated with any means of concentration, exercises no discrimination between wanted and unwanted sound sources.

A practical example of this difference is to be found in any restaurant where there is dinner music. Despite the high level of ambient noise, you can carry on a conversation or listen to the music and enjoy doing either one but not both at the same time. But imagine the result if a microphone were placed on your table for a broadcast! Very little of the music would be heard, and the few strains coming through would sound far, far away. The radio listener would hear a hopeless hodgepodge of voices, noise, and confusion.

First, then, let's do away with the idea that the microphone is an extension of the human ear. This applies equally to microphone techniques for AM and FM. In practice, every effort must be made to utilize the possibilities and limitations of the mike in order to deliver an exact replica of the original program content to the ears of the radio listeners.

Frequently we hear it said that microphone techniques are different for AM and FM. As to this, there are ample grounds for disagreement. Discussions with control-room operators and production men seem to indicate that they do not know how to set up for optimum on FM. Therefore, they adopt the attitude that FM and AM techniques are different and, since the AM audience is larger, AM practices should be favored.

Actually, experience shows that the rule should be: "Precise or sloppy techniques show up more on FM than on AM." In other words, the difference between careful and careless handling of a program is disclosed on AM to only a limited degree, but FM listening shows up the difference very clearly, even with a set of no more than average audio capabilities.

In this connection, there is another point that calls for revision of control-room practice at many stations. It is not unusual to find three speakers in one control room, for the operator may be called upon to keep up with the program on the air, another under rehearsal, and a third being aired by a local competitor. Under such conditions, critical listening by the operator is impossible!

All this leads up to the fact that FM has set new and very high standards of studio practice. Haphazard program setups that "get by" on AM may prove to be poison for FM. This is no exaggeration. On the other hand, the employment of high-fidelity methods for FM results in improved quality on AM. This will be explained in detail.

Understanding Response Patterns

In so far as program setups are concerned, the foremost characteristic of a broadcast microphone is its response pattern. There are several important factors which must be considered when using a microphone pattern to obtain a desired result.

The basic point to keep in mind is that a response pattern as illustrated for a given mike is plotted in a perfectly dead room, to avoid all reflections of sound waves. But when a microphone is set up in a studio room, although the theoretical response pattern does not change, the mike is acted upon by reflections which vary in direction and magnitude according to the shape of the walls and the ceiling and their ability to absorb or reflect sound waves. This will be made clear by the hypothetical case of a setup involving two sound sources and a bidirectional microphone.

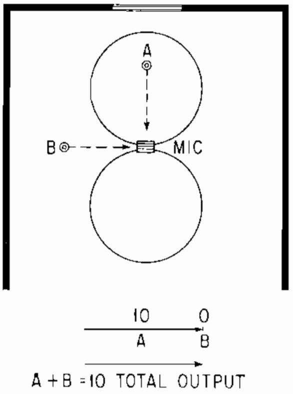


Fig. 1-43. Bidirectional pattern in dead room.

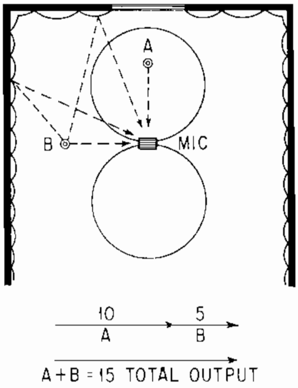


Fig. 1-44. Results are modified in live studio.

Figure 1-43 illustrates the ideal response curve of a bidirectional mike in a completely dead room. Sound sources *A* and *B* are of the same intensity and the same distance from the mike, but *B* is directly on the zero-response axis. Let us say that each source represents 10 units of sound. Since sound source *B* will excite both sides of the ribbon equally, no movement of the ribbon will result from this source and no output voltage will be created in the microphone. Therefore, the total output voltage will be 10 units and consist only of the impulses received from *A*. Thus the pattern holds true.

Figure 1-44 shows the same setup in a live room. It is still true that *B* will excite both sides of the ribbon equally, resulting in no response to the direct wave, but now we have reflections. Sound will be reflected from the walls back into the sensitive side of the mike and, although reduced in intensity, will add to the 10 units of sound from source *A*. The difference now between the two sound sources is not only one of intensity but ratio of reflected to direct sound. Naturally this ratio is greater for sound source *B* than for source *A*.

It is, of course, obvious that there is no such thing in broadcasting as a perfectly dead studio. This example is, therefore, rather crude but serves to illustrate the basic idea of how acoustical treatment influences the polar action upon a microphone. This understanding is imperative from an operational point of view.

While we are on the subject of response patterns, it is well to be sure that it is clear as to just what information they are meant to convey. Figure 1-45 shows the polar response pattern of a particular cardioid mike, plotted for four different frequencies against the ideal cardioid curve. This shows that there is a narrower response angle at higher frequencies than at lower ones because high frequencies tend to travel in beams.

The curves at the left in Fig. 1-45 illustrate, for example, that on 50 cycles the response is down about 5 db at 90° with respect to its response for the same distance at 0°. It will also be noted that for 9,000 cycles the response at 90° is down about 6 to 7 db. Also, at 90° the 9,000-cycle response is about 11 db lower than the zero-axis 50-cycle response. Since, in broadcasting, we are concerned not only with wanted and unwanted sound, but all shades in between, the individual response patterns of a mike prove extremely useful if utilized properly. From this discussion we have four fundamental operating points for the microphone:

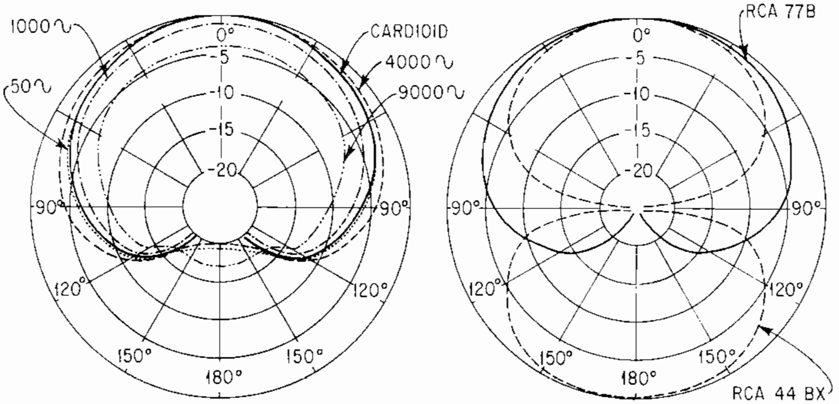


FIG. 1-45. *Left:* Cardiod. *Right:* Unidirectional and Bidirectional RCA types.

1. If a sound source must be moved about the mike, loss or response can be compensated for, if desired, by moving the mike closer to the source.
2. The ratio of reflected to direct sound can be raised in a sufficiently live studio by using greater angles from the zero axis of the mike. This is especially true of bidirectional microphones.
3. The more live the studio, the greater will be this effect.
4. High-frequency sound sources must be more nearly on beam for a given distance to achieve the same intensity of response as lower frequency sound sources.

To this latter point should be added the note that a bidirectional microphone has a greater deviation in angular response between high and low frequencies. Also, the cardioid, or unidirectional, instrument has a much wider angle of response at all frequencies than a bidirectional mike.

This is shown in Fig. 1-45, where the 1,000-cycle curve of an RCA 77 B unidirectional mike (solid curve) is superimposed on the 1,000-cycle curve of an RCA 44 BX velocity (bidirectional) microphone. It should be observed that at 60° the relative response of the 77 B is down only about 2.5 db whereas the 44 BX at 60° is down about 6 db. The very great difference at 90° is clearly shown. This is typical of all makes of broadcast microphones when comparing the unidirectional and bidirectional patterns.

Studio Acoustics

The nonstandard acoustical characteristics of broadcast studios are the outstanding factor that has prevented any establishment of definite standards in microphone setups. If there were such a thing as a standard studio, designed to approach as nearly as practicable the ideal condition of sound dispersion, the setup for any particular musical organization would be a simple matter anywhere when once worked out. Naturally, such is not the case. It is probably safe to say that there are no two studios anywhere in the world that are acoustically alike.

Right here, the author feels it advisable to bring out a point so far neglected in the scanty literature on mike technique. This point is that a great number of operators and producers (alas, even in FM) do not have adequately designed and acoustically controlled studios in which to work.

Since it is the purpose of this material to present practical information, the author will attempt to show some definite rules that can be used to meet any acoustical conditions. High-fidelity techniques for a good modern studio cannot be applied to most of the studios in use around the country. We shall have to plant our feet squarely on the ground and face the situation as it really exists.

In the modern studio, the walls are live to musical sounds but are broken up acoustically in some manner to avoid standing waves while still achieving a maximum response to diffused, polyphased high-frequency sound. Under those conditions, good tonal brilliance can be obtained with a minimum of microphone and control-board manipulation. This is the type of design we need really to practice proper microphone technique.

The Single Announcer

The single announcer is the logical starting point for our discussion of mike technique. It must be understood that we are not concerned at present with announcing over a background of music or any form of dramatic presentation. You may ask: "What is there to discuss, then? The announcer just steps up to the mike or sits down in front of one and talks!"

You're right. He does. But the fact of an error does not justify it.

Announcing alone occupies a considerable portion of the broadcaster's schedule. Correct voice transmission is so very important to radio because we do not have the sense of sight to help our impressions; the voice is the complete medium of expression. The intake of the breath, the most subtle inflections, the style of delivery, the original voice timbre, all are necessary to the listener. Any or all of them may be severely affected by the announcer's relation to the mike.

Those of us in the technical end of radio must at some time of our careers realize that engineering training does not develop an appreciation of artistic values or sense of showmanship. We are very apt to lose sight of the real reasons behind the keys, faders, and perfectly matched impendances of the control system. They are designed this way so that the electrical impulses may correspond to the thunderous crescendos of Wagner's *Die Walküre* or the light, delicate strings of Debussy's *Festivals*. It is with the intangible qualities of human experience, expressed by great artists through the moods of music, that the wires and switches and dials and knobs of the technical department are concerned. As we grow ever more conscious of this, we come to see our work in its true relation to the service of radio to the listening audience.

But to get back to the announcer and our starting point in high-fidelity microphone techniques. Mugging the mike is a strongly entrenched and deeply rooted habit. But the announcer must be kept away from the microphone. He will probably object. He may refuse. Some announce desks have microphones permanently mounted on them, and if the announcer moves back, he must hold his script in an uncomfortable position, without an armrest. This is plainly and simply an engineering error. Like fingerprints, there are no two voices exactly alike. For every voice there is a definite relationship to the microphone which allows the most natural and pleasing reproduction.

For voice work alone, 2 ft is the minimum distance from the face to the microphone that will assure naturalness of that voice! A distance of 2 ft, incidentally, should be used only for the softest voices. Compare this with your own studio-operating practice. What is the distance your announcers use? Probably somewhere between 4 and 12 in. Voice waves at this distance from the mouth and throat cavities do not create electrical impulses that correspond to the natural character of that particular voice.

Do this as an experiment: On rehearsal, set up microphones (in addition to the regular announce mike) 3, 6, and 9 ft away. Stagger them enough so that no mike will be in front of another. If the regular microphone is immediately in front of the announcer's face, you will have to move it lower or to one side. Don't tell him what you are doing. Just say you are testing mikes. If he is told to start reading at a distance from one microphone and then to move closer, he will subconsciously alter his volume and you will not get a natural check.

Now turn only one microphone on at a time. Start with the farthest mike. Unless you are so conditioned to hearing the mugging voice that you can accept no other, you will find a new experience in naturalness of voice transmission. A distance will be found where the voice begins to sound hollow in a live studio or thin in a dead one. Use the distance just a shade closer than this point.

In small announce booths, where space is at a premium and where distance would create a barrel effect owing to the proximity of the studio wall to the microphone, the mike should be suspended over the announcer's head at a distance of several feet. We are borrowing this technique from television, where the mike must be kept out of the range of the camera and is often as much as 15 ft from a performer. It should be borne in mind, however, that the sound in television is only a secondary expression to the picture. In other words, all the intent and meaning need not be embraced in sound, as in audio broadcasting.

FIG. 1-46. Setup for interview in small room.

This same technique is most convenient when two persons are seated at a table and using a single mike as illustrated in Fig. 1-46. The table top should be deadened by acoustical treatment or by the use of a heavy cloth cover to prevent reflected sounds from entering the mike.

How Many Microphones?

In an approach to the study of specific types of program setups, the question of the number of mikes will invariably arise, especially on a large show. Keep always in mind the previous discussion on the monaural character of the system and the lack of focusing power unless it is deliberately used as a means of concentrating the attention.

The greatest weakness in mike setups for large shows has always been the use of too many microphones. There is bound to be some distortion, however slight, in multiple-mike setups due to the time lag of sound waves which create phase additions and subtractions at the various pickup positions. This source of distortion, however, is only minor compared with the other faults of this technique. Aside from the operational difficulties of handling a large number of channels on the mixing panel, with greatly increased chances of error, the control man and his board take the place of the conductor. All the dramatic interest, the emotional pattern written into the original score, plus even the conductor's interpretation are placed in the ratio of fader adjustments and the reactions and psychological temperament of the operator. In other words, too many variables are injected between the performers and the listeners.

Let's establish a foundation upon which we can build a workable structure to determine the correct number of microphones for a given show. Let's also be practical and realize that many operators have neither the very latest studios nor an adequate amount of rehearsal time.

1. Whenever it is possible in the time allotted for setting up, arrange your performers about a single microphone (following suggestions given later for each type of show) so that the over-all balance is correct. If you do this, you achieve balance by proper positioning rather than by mixing various sources on the control board.

2. Perhaps your time is running out and you are still having trouble with a particular section in obtaining balance. This is more apt to occur in a dead studio than in one which is acoustically live. Another mike will have to be used on the troublesome section. However, use of the second pickup can probably be limited to particular spots in the show, such as rhythm-section accentuation of an orchestra as required by the score.

3. Some of the more complex shows do require more than one microphone. Take, for example, a variety show consisting of a drama cast, a chorus, and an orchestra. Remember that the microphone does not focus attention as your ears do in the studio. Of course, it is likely that a program of this type will originate at one of the larger stations having modern studios. The more rehearsal time you have, the less the number of microphones necessary, to the point where the absolute minimum is reached. So much for the basic theory of microphone technique. Let's go on with more specific program setups.

Picking up the Piano

The single-piano pickup is the simplest setup, since it is perhaps the least affected by acoustical nature of the room. No matter how softly the pianist plays, as long as he is unaccompanied by other instruments, the microphone should not be placed up under the lid. The distortion arising from the close proximity of large physical objects to the microphone is well known. It should then be obvious that a pickup under the lid and close to the sounding board will not allow natural transmission of the piano tones. Close-miking almost any instrument makes it necessary to hold down the volume, with great loss of musical brilliance. It is true that many operators have become so accustomed to this type of piano setup that, as is the case with the close-talking announcer, the sound may be familiar, but it is not natural reproduction. We must remember that it is the business of the broadcaster to transmit the natural sound of the original program content.

Here is the best method of determining the setup for a single piano: Start with a distance of 20 ft, head high. In a dead studio, this distance will probably result in a thin response, especially on low passage. In live studios, the sound may be too reverberent for clear-cut transmission. Move the microphone in on a line drawn through the center of the sounding board until the tones are full-bodied, with just the right amount of reverberation. This distance is seldom less than 8 ft and will allow tonal brilliance and balance between lows and highs that is sacrificed in close-up technique.

Now comes the final check for balance between bass and treble, in other words, the check of the player's left- and right-hand pressures. If the pianist has a heavy right hand and bass response is somewhat weak in relation to the highs, keep the mike at the same distance but swing it toward the tail of the piano. This method increases the response from the bass strings. If the pianist has a heavy left hand, with a relative loss of highs (this lack of highs is also apt to occur in dead studios), the mike should be moved toward an imaginary extension of the keyboard. This will increase response to the treble strings and decrease that from the bass strings.

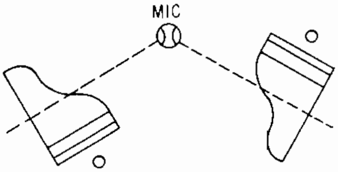


FIG. 1-47. Orientation for a two-piano team.

The twin-piano team imposes only slight additional requirements. Figure 1-47 illustrates the most satisfactory orientation. The temperaments of the pianists must, of course, be considered, and the lead piano given prominence by moving the mike closer to that piano if the accompanist is heavy-handed. The procedure for bass and treble balance should be followed, not by moving the microphone, but the piano itself.

Vocalist and Piano

The distance of the vocalist from the mike, the distance of the mike from the piano, and the distance of the vocalist from the piano must be considered in this setup. There is no excuse for using more than one microphone unless the time allowed for rehearsal is zero.

The first requirement is to listen to the vocalist in the studio. Does he or she sing out with the chest muscles, using a large volume and dynamic range? Or is the vocalist the crooner type, using only the larynx and throat for emphasis? Every vocalist is in one or the other general category.

One who sings out with full volume should be placed 12 to 6 ft from the microphone when a piano alone is used as background. On rehearsal, always start with the greatest distance. The goal is to use the lowest volume and the highest volume without having to ride gain on the fader control. This part of the balance can always be achieved by careful rehearsal checks. The balance between vocalist and piano accompaniment is not always so simple. A good pianist or one familiar with a particular vocalist's style will automatically adjust his volume to the pianissimo and crescendo of the singer.

A bidirectional mike should be placed about 8 ft from the piano, with the vocalist on the opposite side at the distance determined by trial. It is well to point out here that a very common error is in taking a vocal solo too literally. The presence of the piano must always be there, with only slight emphasis on the voice. It should be a blend with, of course, the voice always a little predominant, but not with a weak background of piano tones, as is often heard.

When the pianist insists on playing so loudly that the accompaniment smothers the vocalist (some pianists cannot alter their volume and still play well), the dead side of the vocalist's microphone must be turned toward the piano. This is almost always the only adjustment necessary from the 8-ft distance between mike and piano. If the studio is very live and the piano tones are still too prominent, turn the piano around so that the lid opens toward a wall of the studio. Don't at any time move the vocalist closer to the mike if it is necessary to ride gain on the natural dynamic range of the voice.

Setup for Small String Groups

Small salon groups, string quartettes, or hillbilly groups, playing in intimate style, require good instrumental definition. This calls for comparatively close mike setups, but not too close! The author is always hesitant about using the word "close," since the reader is apt to take it as meaning directly into the face of the instrument.

Consider a small salon orchestra, generally consisting of several violins, a viola, a cello, a string bass, and sometimes a piano. Because of their comparative volume they are usually placed in that order from the microphone. Figure 1-48 illustrates the general orientation of such a group with the mike.

Now assume that the approximate distances are violins 4 ft, viola 6 ft, cello 8 ft, and string bass 10 ft, with piano somewhat off mike at 10 ft. If the violins are too predominant for proper sectional balance, usual practice is to move the violins farther back or to one side in a less sensitive zone or else to bring the other instruments in closer.

However, remembering the focusing-power principle, it is clear that quite a range of sectional balance can be obtained by the simple expedient of adjusting the microphone height and tilt, as shown in Fig. 1-49. If the violins are too predominant, raise the mike and focus on the other instruments. If the violins are weak, the mike should be lower and focused on them. This is a better method than moving the predominating instruments to one side in a less sensitive area of the mike, since the higher frequencies containing the overtones are very important for wide-range pickups.

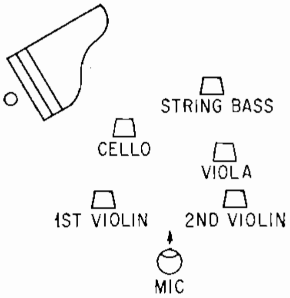


FIG. 1-48. Orientation for a salon orchestra.

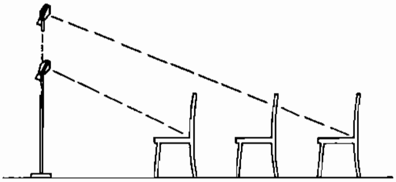


FIG. 1-49. Adjusting microphone for balance.

There is little difference in pickup for this type of musical organization between dead and live studios, since the setup must be intimate in character, with high direct-to-reflected sound ratio, minimizing the effect of the acoustical nature of the studio.

Setups for Small Orchestras

A large number of organizations presenting popular, serious, or variety music comes within the small-orchestra category. There may be a combination of brass, strings, and reeds, numbering anywhere from 4 to 15 musicians.

Again the first step is to visualize the instruments in comparative power output. From softest to loudest, they are:

1. Violins, trumpets or trombones (muted), guitar
2. Clarinets, saxophones, xylophone, vibraphone
3. String bass
4. Piano
5. Trombone (open belled), trumpets (open belled).
6. Traps, bass drums, guitar (electrically amplified)

These are the most likely instruments to be encountered in such a setup. As before, the conventional approach is to arrange them in the order listed from the single microphone.

Look now at Fig. 1-50. This is a live-studio practice, starting with the violins at about 8 ft. When initially checking the balance of sections, remember the height and tilt adjustment for focusing power to obtain proper blend. Then, and not until then, try moving a troublesome section.

If you think it necessary to move instruments, keep these principles in mind: A predominating section may be too loud, not because the relative distances between instruments are incorrect, but because the microphone is too close to the entire outfit. Move the mike back.

A weak section may be too soft, not because it is too far from the mike, but because all instruments are too close to the microphone. Move the mike back.

In other words, the farther back a microphone is placed (within the limits of acoustically allowable distance), the better the chance of a good balance between all sections.

Another very important item is the treatment afforded muted trumpets or trombones. When their bells are muted, the instruments must be very close to the microphone. This means really close, about 2 ft. If the players cannot or will not step from their regular positions to one immediately in front of the mike, a separate microphone must be spotted just in front of that section. Obviously it is to be used only when the instruments are muted.

Now consider a studio of older design with dead characteristics. When the musicians number around 12 to 15, it is often difficult to get good sectional balance with the plan shown in Fig. 1-50. Even though the farther instruments may contribute about the same number of volume units, the pickup may be thin, because the dead studio does not reinforce the harmonics and overtones. Also the mike must be a little closer in a dead studio, emphasizing the discrepancy in sectional presence.

In nearly every case, however, best results are obtained with one mike and by using the setup illustrated in Fig. 1-51. The mike is a bidirectional ribbon type. The instruments must be more nearly on beam, owing to the narrower angle of response in comparison with the unidirectional mike employed in Fig. 1-50 and with the dead acoustics of the studio. More time and movement of players will be necessary to get this setup exactly right, but it is far better than the usual procedure of using additional microphones.

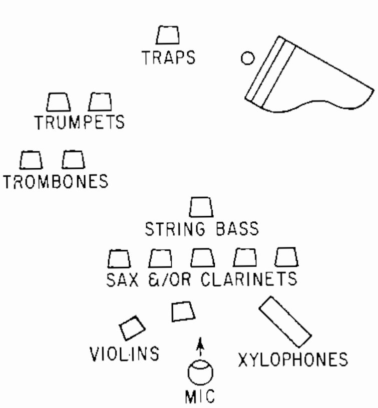


Fig. 1-50. Conventional one-microphone plan.

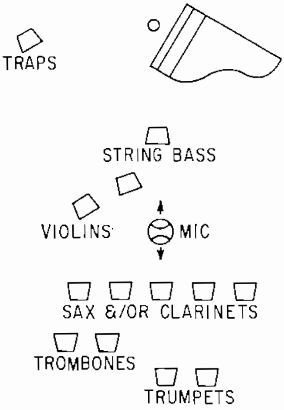


Fig. 1-51. Improved pickup location.

How to Add a Vocalist

A vocalist with the type of musical program just described imposes special problems unless the organization is thoroughly trained in prior broadcast-production technique.

The ideal arrangement would be for the vocalist to stand in front of the orchestra, facing the mike at a distance of several feet. This arrangement, however, is often not practical as, for instance, when the mike is raised and slanted so as to obtain proper balance of instrumental tones.

Where such a situation occurs, there is no alternative but to use a second microphone for the vocalist, preferably a unidirectional type, with the dead side toward the orchestra. This mike can be used for the announcer also.

Symphony Orchestras

The setup for a large symphony orchestra should be based upon exactly the same principles as heretofore discussed, except that the grouping of instruments, the use of a chorus, and the type of musical score make the problems much broader in scope. Fortunately, such programs are not usually attempted in an inadequately designed studio.

Generally, the usual physical arrangement of the orchestra for regular audience listening will be satisfactory for broadcast purposes. On the initial trial of the main orchestra microphone, several mikes should be suspended at the most likely pickup positions in order to avoid the confusion of moving mikes. The general area for these microphones is 15 to 20 ft high and 15 to 25 ft in front of the violin section. Figure 1-52 illustrates a typical grouping of a large symphony orchestra.

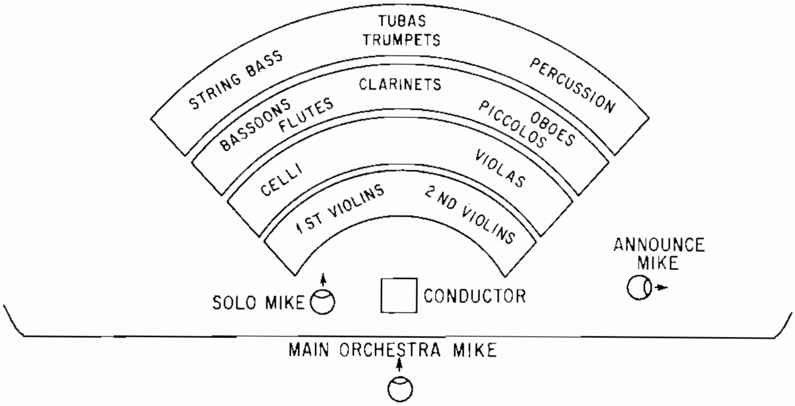


FIG. 1-52. Symphony orchestras may require solo and section mikes for highest fidelity.

If a vocalist or instrumental solo is called for, it is almost always necessary to use a second mike to achieve proper sound perspective. Remember that vocal or instrumental solos are not to be entirely predominant; the orchestral accompaniment must be very much present. Always try to get the conductor to listen to a monitor speaker for a final check on balance, or get some responsible member of the organization to pass on it. The very best control and production men do this simply because every symphony organization has its own arrangement of score or possibly a distinct interpretation of the original score. This individuality must be conveyed to the listeners. Thus, many times, a slight rearrangement of instruments in relation to the microphone is found necessary.

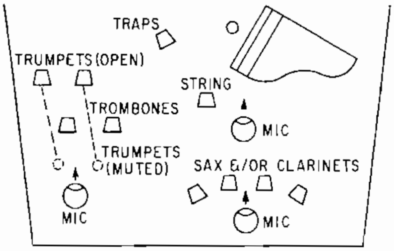
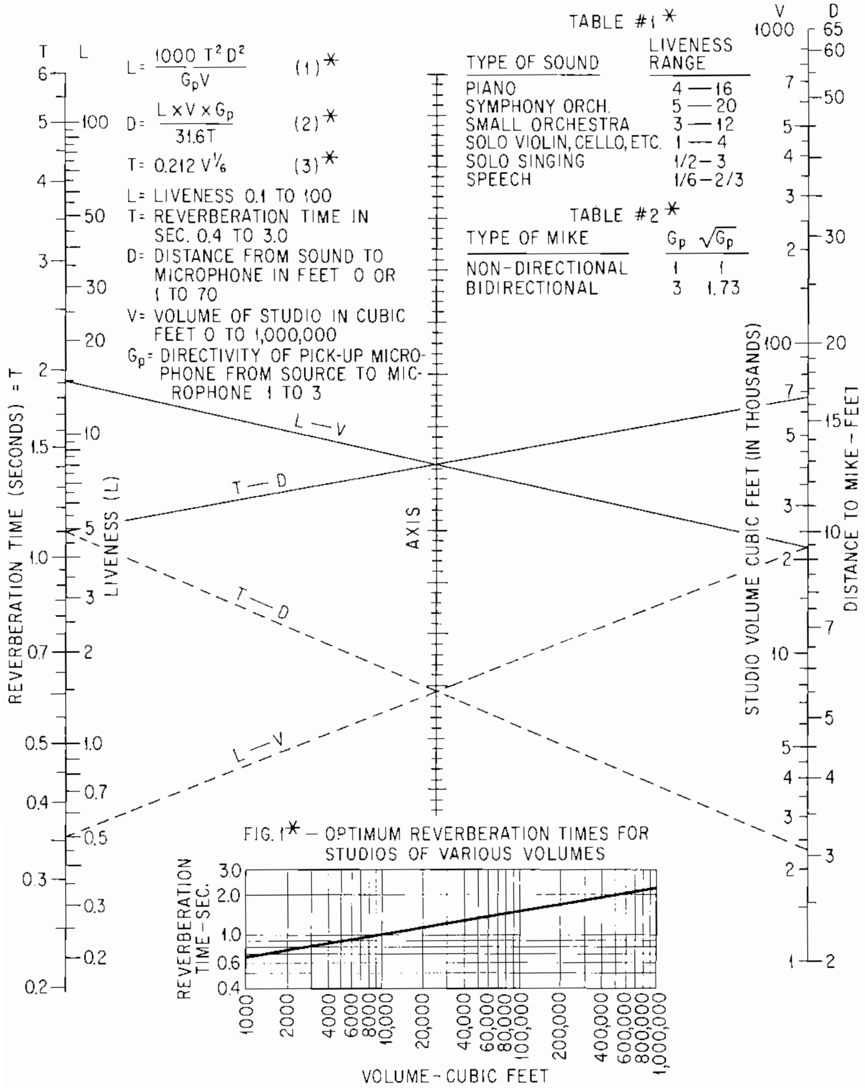


FIG. 1-53. Mike setup for dance orchestra.

In spite of the usually superior results obtained with a single, well-orientated microphone, it is often necessary to deviate from this practice for true high-fidelity pickup. The main orchestra microphone, back far enough to obtain the proper blend of all instrumental tones, will faithfully pick up the delicate, distant tonal beauty of the violin passages in *Clair de Lune*, for example. Most music lovers, however, criticize this same microphone setup for such numbers as the Strauss waltzes, where the tonal perspective of the strings should be closer and more strident in quality.

Many leading conductors and producers of symphony broadcasts insist on an added mike suspended directly over the strings or other sections to be turned up only on cue. This procedure supplies the missing psychological factor of microphone-to-sound perspective. When a choir is used with a symphony orchestra, it is also necessary to use a separate mike because of the spread of the total combination in order to obtain focusing power.



$$L = \frac{1000\,T^2D^2}{G_pV} \qquad (1)^*$$

$$D = \frac{L \times V \times G_p}{31.6T} \qquad (2)^*$$

$$T = 0.212\,V^{1/6} \qquad (3)^*$$

L = LIVENESS 0.1 TO 100

T = REVERBERATION TIME IN SEC. 0.4 TO 3.0

D = DISTANCE FROM SOUND TO MICROPHONE IN FEET 0 OR 1 TO 70

V = VOLUME OF STUDIO IN CUBIC FEET 0 TO 1,000,000

G_p = DIRECTIVITY OF PICK-UP MICROPHONE FROM SOURCE TO MICROPHONE 1 TO 3

TABLE #1*

TYPE OF SOUND	LIVENESS RANGE
PIANO	4 — 16
SYMPHONY ORCH.	5 — 20
SMALL ORCHESTRA	3 — 12
SOLO VIOLIN, CELLO, ETC.	1 — 4
SOLO SINGING	1/2 – 3
SPEECH	1/6 – 2/3

TABLE #2*

TYPE OF MIKE	G_p	$\sqrt{G_p}$
NON-DIRECTIONAL	1	1
BIDIRECTIONAL	3	1.73

FIG. 1* — OPTIMUM REVERBERATION TIMES FOR STUDIOS OF VARIOUS VOLUMES

*COURTESY OF WESTERN ELECTRIC CO.

FIG. 1-54. Nomograph for microphone distances in liveness broadcasting. (*Reprinted by permission from Tele-Tech magazine.*)

Constants $V = 22{,}000$ cu ft; $T = 1.1$ sec.

Example 1: (solid lines) placement of general microphone. From Table 1 use liveness of 15. Connect 22,000 on V and 15 on L. Mark reference on the axis. Then extend a line from 1.1 on T through reference on axis to 16.5 ft on D. Answer: 16½ ft from mike to sound source.

Example 2: (dash lines) placement of solo vocal microphone. From Table 1 use liveness of ½. Connect 22,000 on V and ½ on L. Mark reference on the axis. Then extend line from 1.1 on T through this reference to 3 ft on D. For bidirectional mike multiply 3 ft by $\sqrt{3}$ or 1.73. This yields 5 to 6 ft for actual distance.

Notes on Field Setups

Field setups are an entirely different matter. The musical instruments must usually be placed more in a straight line owing to lack of depth of the platform. Added to this is the inevitable noise and confusion about the point of origin. It may be argued that really high-fidelity transmission is impossible from such a broadcast, and this is true. But FM listeners especially will appreciate any pains taken to improve the pickup.

Multiple-microphone arrangements are absolutely necessary for such an orchestra of even medium size.

Figure 1-53 illustrates a three-microphone treatment of a typical dance orchestra playing in the open. Always strive to obtain a good balance with the minimum number of mikes, taking into consideration the usually heavy background noise. It is almost always necessary to use a microphone for each group of instruments, as shown in Fig. 1-53, to give the section playing the lead or melody at any particular time the highest intensity. But remember that the presence of the other sections is important.

Conclusion

It is apparent to the experienced broadcast man that many types of program setups have not been treated in this article. Indeed, such a treatment would require a full-size book. The author has attempted to take up only those situations most commonly encountered.

There will, no doubt, be some who have honest disagreements with parts of this discussion. The author extends an invitation of correspondence to any reader who may care to offer comment or criticism. Progress in any line of endeavor can be achieved only by the inquisitive mind and earnest doubts of traditional practices. Microphone-setup techniques in particular and operational engineering in general are in need of exhaustive, wide-open discussion.

Part 2

COST ESTIMATING FOR TELEVISION FACILITIES

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INTRODUCTION

The following information is for preliminary estimating only and is based on costs in the Northeastern part of the United States. When using this information, make sure that all concerned realize that these are quick estimates of relatively good accuracy but should not be considered exact costs. Final pricing can be determined after consultation with the architect or engineer and obtaining contractor's quotations.

Cost-estimating factors will vary with current labor rates, location, union jurisdiction, climate, etc. The cost factors shown herein can be adjusted to suit these local conditions. Make sure that you know your own local situation in so far as these items are concerned.

Where there are improvements to land, make sure that you have enough basic information to include all necessary items. Certain property might require drilling and blasting, special provisions for drainage, etc.

These cost factors presuppose good construction materials and methods. In some circumstances cheap construction may be warranted. However, it is believed that good construction pays in the long run and that it is better to save on operating and maintenance costs rather than on capital expenditures.

The following information does not include equipment or tower costs, which are covered:

Table 2-1. Construction-cost-estimating Factors—TV Plants

Total Estimates

New transmitter buildings	$21/sq ft
New studios and offices	$32/sq ft
Studio conversions (shell available)	$17/sq ft

Component Estimates

Studio flooring	$0.55/sq ft floor area
Office flooring	$0.35/sq ft floor area
Studio acoustic treatment	$0.90/sq ft area covered
Other acoustic treatment	$0.55/sq ft area covered
Studio lighting and rigging	$10/sq ft floor area
General electrical work	$2.25/sq ft floor area
Audio/video wiring	$1.50/connection
Air-conditioning plant	$1,000/ton of refrigeration

Table 2-1. (*Continued*)

Improvements to Land

Land—clearing and grubbing	$600/acre
Excavating:	
Power (use on large jobs)	$1/cu yd
Hand (use on small jobs)	$5/cu yd
Grading:	
Rough	$0.35/cu yd
Finish	$0.15/sq yd
Roadway and parking area	$2.50/sq yd
Fencing	$3/ft

SAMPLE PROBLEMS

Example 1. Conversion—Studios and Offices

Existing building is 200 by 110 ft, seven stories high.

110 × 200 × 7 = 154,000 sq ft

Deduct 28,000 sq ft for studios that are two stories high.

154,000 − 28,000 = 126,000 sq ft
126,000 × $17 = $2,142,000 estimated cost

Note: In 1953 this actual job priced out at $1,731,000. Multiply 1,731,000 by the increase in cost from 1953 to 1959 to get 1,731,000 × 5.1/4.2 = 2,100,000.

Example 2. New Studio—Office Building

To be built on property already cleared. Building is to be 90 by 80 by 20 ft and will house two studios, one 60 by 40 by 20 ft, the other 40 by 20 by 20 ft, with the remaining area (two floors) devoted to offices, technical space, program space, etc.

Total area: 90 × 80 = 7,200 sq ft

Studio area: 60 × 40 = 2,400
40 × 20 = 800
3,200 sq ft

7,200 − 3,200 = 4,000 sq ft
4,000 × 2 stories = 8,000 sq ft other space
3,200 sq ft (studio) + 8,000 sq ft (other) = 11,200 sq ft
11,200 × 32 = $358,400

Example 3. Transmitter-plant Estimate

Land:	
Size, cost: 20 acres at $1,200	$24,000
Improvements to land:	
Clearing 5 acres at $600	3,000
Grading and excavating negligible	—
Roadway and parking lot, 400 sq yd at $2.50	1,000
Fence 500 ft at $3	1,500
Miscellaneous, drainage, etc.	2,500
	$32,000
Balance brought forward	$32,000
Transmitter building:	
70 × 35 = 2,450 sq ft	
2,450 sq ft × $21	51,450
	$83,450

Example 4. Flooring Cost Estimate

Same studio and office building described in Example 2.

Studio area:	
3,200 sq ft at \$0.55	\$ 1,760
Other area:	
8,000 sq ft at \$0.35	2,800
Total	\$ 4,560

Example 5. Acoustic-treatment Cost Estimate

Studio 60 by 40 by 20 ft with wall surfaces not treated from floor to 5 ft above floor.

$$\begin{aligned} \text{Area covered} &= 60 \times 40 + 2(40 \times 15) + 2(60 \times 15) \\ &= 2{,}400 + 1{,}200 + 1{,}800 \\ &= 5{,}400 \text{ sq ft} \\ 5{,}400 \times \$0.90 &= \$4{,}860 \end{aligned}$$

Totals for building described in Example 2:	
Studio 60 by 40	\$ 4,860
Studio 40 by 20	2,340
	\$ 7,200
Balance brought forward	\$ 7,200
Office ceilings:	
8,000 sq ft × \$0.55	4,400
Total	\$11,600

Example 6. Air-conditioning Cost Estimate

Method:

1. Determine heat load in kilowatts (see Table 2-2).
2. Determine volume of space in cubic feet.
3. Based on six air changes per hour, divide volume by 10 to give cubic feet per minute to be cooled.
4. Allow 1 ton of refrigeration per 400 cfm plus 1 ton per 4 kw.[1]

Table 2-2. Heat Loads

	Watts
General lighting	4/sq ft
Studio lighting (monochrome)	25/sq ft
Studio lighting (color)	100/sq ft
Persons	150/each
Equipment radiation	600/rack

NOTE: For the studio and office building described in Example 2:

Monochrome studio lighting: 3,200 sq ft × 25 watts/sq ft = 80 kw
Other lighting: 8,000 sq ft × 4 watts/sq ft = 32 kw
Staff and audience: 150 × 150 watts = 22.5 kw
Equipment: 25 racks × 600 watts/rack = 15 kw
149.5 kw

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[1] These factors are based on Northeastern United States. There will be changes for different design conditions in different areas. See "ASHAE Handbook."

Table 2-2. (*Continued*)

$$\text{Volume of building} = 90 \times 80 \times 20 = 144{,}000 \text{ cu ft}$$

$$\frac{144{,}000}{10} = 14{,}400 \text{ cfm}$$

$$\frac{149.5 \text{ kw}}{4} = 37.4 \text{ tons}$$

$$\frac{14{,}400}{400} = 36 \text{ tons}$$

$$37.4 + 36 = 73.4 \text{ tons approx.}$$

73.4 tons × 0.70 diversity factor[2] = 52 tons

52 tons at \$1,000[3] = \$52,000

Example 7. Lighting and Rigging Cost Estimate[4] *(per Square Foot of Studio)*

Table 2-3. Cost Factors

Item	*Monochrome (100 fc)*	*Color (400 fc)*
Connector strips	1.20	1.40
Fixtures	1.40	2.20
Light control	2.30	2.75
Installation	2.50	2.75
Subtotal	7.40	9.10
Rigging (installed)	2.50	2.50
Subtotal	9.90	11.60
Add for 10 scene preset board	3.50	5.25
Total	13.40	16.85

For the studios described in Example 2: 60- by 40- by 20-ft studios complete with rigging and adjustable battens, lit for monochrome, using autostat board and patch panel for light control.

$$\begin{aligned} 60 \times 40 \times 9.90 &= \$23{,}760 \\ 40 \times 20 \times 9.90 &= 7{,}920 \\ & \$31{,}680 \end{aligned}$$

Table 2-4. Power-service Estimates

	Watts
1. General service	4/sq ft
2. Studio lighting, monochrome	25/sq ft
3. Studio lighting, color	100/sq ft
4. Camera chains, orthicon	1,500
5. Camera chains, vidicon	650
6. Equipment racks	1,500
7. Air conditioning	1,000/ton
8. Miscellaneous *	

* Don't forget to include office equipment, cleaning equipment, shop tools, elevators, electric signs, and other applicable items.

Advances in equipment design, the use of transistorized equipment, etc., are reducing these loads from year to year. For some applications, fluorescent lighting has been used with success. Ultimately, there will be considerable reduction in power service and air-conditioning requirements.

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[2] Allow 0.70 diversity factor on the basis of a few large audience programs and limited back-to-back studio operation.

[3] Some areas in the United States may be as little as \$600 per ton.

[4] Based on New York City electrical costs of approximately \$6 per man-hour.

In the building described in Example 2:

	Kilowatts
Studio lighting	80
Other lighting	32
4 orthicon chains at 1,500	6
2 vidicon chains at 650	1.3
25 racks	37.5
Total	156.8
Balance forward	156.8
52 tons air conditioning	52
Miscellaneous and reserve	50
Total	258.8

Table 2-5. Building-trades Wage Scales [*]

Geographical Variations (1957)

Middle Atlantic	1.00
New England	0.86
Southeast	0.77
Great Lakes	0.95
Middle West	0.90
Southwest	0.83
Mountain	0.83
Pacific	0.91

[*] Source: Bureau of Labor Statistics.

Table 2-6. Building-cost Indices [*]

Year	*Labor*	*Material*	*Total*
1940	1.0	1.0	2.0
1945	1.1	1.3	2.4
1950	1.6	2.0	3.6
1955	2.3	2.4	4.7
1957	2.5	2.6	5.1

[*] Source: *Engineering News-Record.*

Part 3

STUDIO LIGHTING FOR MONOCHROME AND COLOR TELEVISION

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PLANNING TV STUDIO-LIGHTING FACILITIES

Television is essentially a visual art. High priority, therefore, must be given to the planning of the lighting facilities. Proper planning will result in a high-quality picture at a moderate operating cost. Improper planning will result in excessive operating costs and an inferior picture.

In TV lighting, as in all planning, the requirements should determine the space and the facilities. Therefore, it is strongly recommended that the operations people be part of the planning group and be represented at all meetings related to studio planning and facilities. The cost of the studio-lighting equipment and its installation represents only about 10 per cent of the total cost of the facilities. Lighting is such an important factor in picture quality, however, that due consideration must be given to it in planning. Money spent wisely in the initial design will greatly influence the profit picture later.

The responsibility for designing and building the studio should be vested in a planning group. The planning group should include, but not be limited to, the production supervisor, chief engineer, sales manager, personnel manager, and general manager. This group will work with the architects and consulting engineers in designing and building the studio and transmitting facilities.

The planning group will have all available information regarding the present and future scope of the operation. The group should know which facilities should be built immediately and what provisions should be made for future expansion. The planning group should operate before pencil is put to drafting paper.

Based on surveys by management, facilities can be planned for the live telecast of weather, news, variety shows, disc jockey, dramatic shows, live local commercials, and choral and orchestral groups.

The planning group then converts these decisions into space requirements. The requirements should determine the space, not vice versa.[1] The lighting representative on the planning group will recommend the studio size, ceiling height, location in relation to other facilities, and budget. He will be the most important single influence in deciding the lighting-suspension system, the lighting-control system, and the lighting-fixture complement. He will advise management of the latest developments in these areas and examine the economics of the newer, more advanced systems.

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[1] Not always possible.

LIGHTING FACILITIES FOR A TV STUDIO

Let us analyze some of the requirements for lighting facilities for a TV studio. The aim is to provide proper lighting facilities for the telecast of a high-quality picture with an optimum signal-to-noise ratio in a minimum amount of setup time with limited personnel. To do this, the following recommendations are made based on the use of the image-orthicon tube type 5820 and monochrome-broadcast operations. Additional information is provided to plan for future or immediate color broadcast using the type 1854 tube. When costs are cited, they are for average budget consideration and will vary in different labor and freight areas.

Where the phrase "studio area" is used, it is defined as "useful set area," or any part of the studio which can be used to televise from. Generally speaking, this is the complete studio floor.

In planning the lighting facilities for the TV studio, the designers must

1. Provide a safe and rapid means of energizing the lighting instruments and controlling them
   - *a.* By installing ample wiring devices, outlets, and feeders and locating them properly
   - *b.* By providing a properly designed lighting-control center for grouping and dimming lights
2. Specify equipment that is reliable, easily installed and moved
   - *a.* To assure dependable operation
   - *b.* To keep maintenance and time-consuming improvisations to a minimum
   - *c.* To obtain the most favorable casualty, compensation, and fire insurance rate
3. Fixtures should be specified that are
   - *a.* Lightweight for easy handling yet durable to withstand the handling
   - *b.* Easily adjusted, repositioned, and focused
   - *c.* Safely constructed and wired
   - *d.* Adequate in number
   - *e.* Equipped with accessories such as barn doors, diffusers, etc., designed for the fixtures
   - *f.* Able to provide maximum light effectiveness per dollar invested
4. Lighting-control center specified should be
   - *a.* Of sufficient capacity to handle the complete studio-lighting system including patching and dimming
   - *b.* Designed to provide maximum flexibility with a minimum of operations personnel
   - *c.* Safely constructed and wired

SUSPENSION SYSTEMS

Today's lighting practice dictates that, if possible, all lighting equipment should be mounted overhead (Fig. 3-1). This is necessary to permit freedom of camera movement for the multiple cameras used in the average set. From this requirement developed a number of different mounting systems.

The most universal method of mounting lighting equipment is to clamp the fixtures to 1¼- or 1½-in. pipe battens running across the studio. The battens are generally 4 to 6 ft apart. Two additional back-light rails are mounted about 3 ft from the walls, which are at right angles to the main battens (Fig. 3-2).

The pipes should be mounted from the ceiling by chain and S hooks to permit some flexibility as to height adjustment between 12 and 16 ft from the floor level.

Many studios have installed counterweight systems (Figs. 3-3*a* and *b*) to permit rapid and easy raising and lowering of lights in groups or to permit rapid change of equipment. Lateral movement of lights is also facilitated, since the equipment is made easily accessible. Studios having counterweight systems claim that they have paid for themselves in a few years in labor saved and in improved picture quality. Improved picture quality results from the ease of putting a key (or other) light exactly where required.

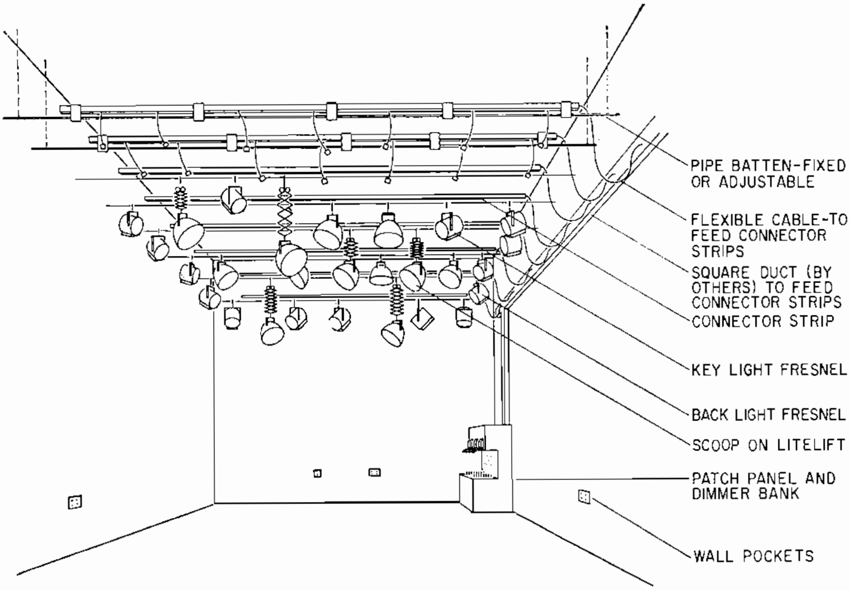

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FIG. 3-1. Studio with pipe suspension system.

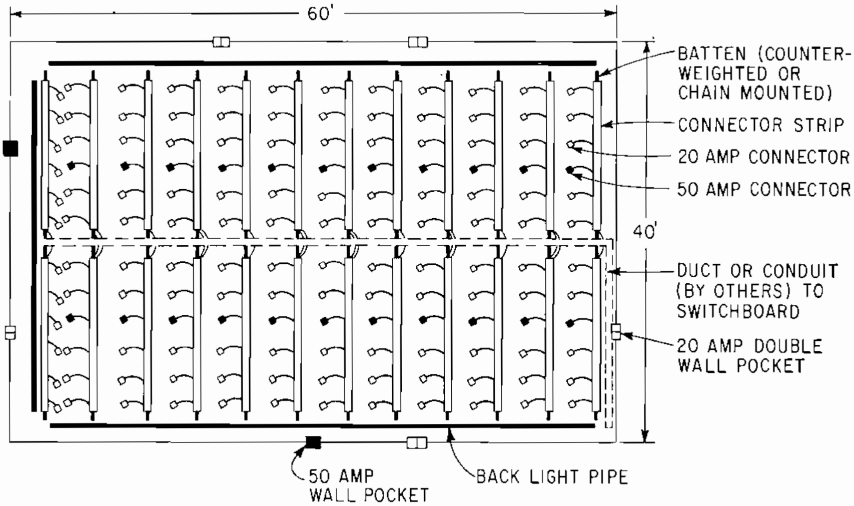

FIG. 3-2. Typical layout for 40- by 60-ft TV color studio.

A few studios have installed motor-operated pipe grids. This system is expensive, but in high-labor-cost areas of extensive studio use, it has proved economical.

Some large studios in New York and Hollywood have installed a complete overhead catwalk system. The lights are set, focused, and serviced from the catwalk. This system, used in conjunction with slide poles, practically eliminates the need for ladders. This is the most expensive suspension system.

Another system gaining in popularity is the mobilrail system (Figs. 3-4*a*, *b*, and *c*). Mobilrail is a system of utilizing pairs of tracks approximately 6 ft apart running across the studio. By the use of double-roller carriers, additional floating mobilrail tracks 12 ft long are carried at right angles to the main tracks. The floating rails can thereby be moved forward and back along the fixed rails. The lighting instruments are in turn mounted on single carriers which run on the floating rails. This permits complete horizontal movement of all lighting instruments singly or in groups. This system when used in conjunction with pantograph light lifts is one of the most flexible available. The price of the mobilrail system is about $1.25 per square foot of studio area. Counterweights cost approximately $250 to $325 per set of lines installed.

FIG. 3-3*a*. WRGB—TV. Showing counterweighted pipe batten in lowered position.

All lighting instruments should be carried from the suspension system by pantograph light lifts (Fig. 3-5). The light lifts permit height setting of the lighting instruments from the floor (by the action of negator springs).

When planning for color, the pipes should be mounted closer together than 6 ft (generally 4 to 5 ft). A higher percentage of light lifts should be provided to permit a greater amount of flat light.

ELECTRICAL DISTRIBUTION

We now have the lights up off the ground. The most usual system for providing current to the lights is the connector strip (or wireway) method (Fig. 3-6). A sheet-steel wireway with pigtail connectors is mounted onto the pipe batten. The pigtails are evenly spaced along the connector strip. The connector strip is held above the

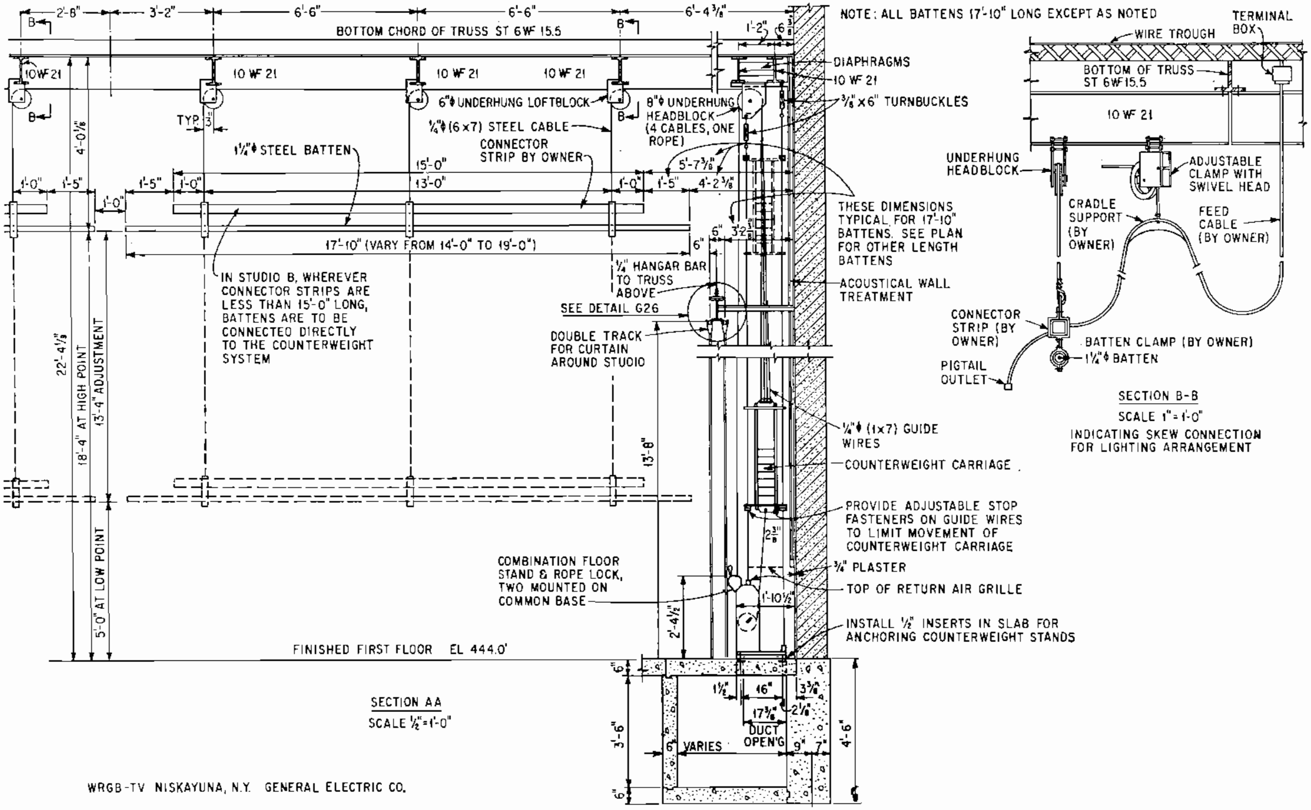

FIG. 3-3*b*. WRGB–TV. Showing details of counterweight system.

pipe batten by brackets so that the lights can still be clamped onto the pipe and the unit plugged into the pigtail connector. At one end of the strip a terminal box is provided. From this terminal box multiconductor flexible cable is carried to a square duct. The duct in turn carries the connection back to the patch panel or lighting-control center. A separate two-wire 20-amp circuit should be carried back from each pigtail connector to the lighting-control center. For safety, it is recommended that grounded pigtail connectors and lighting units be used. Some studios carry a ground wire throughout their entire electrical system.

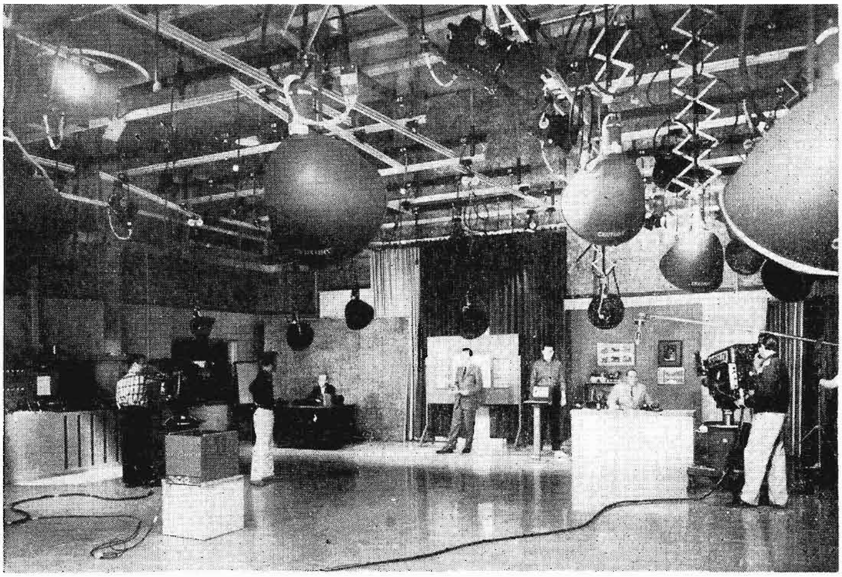

FIG. 3-4*a*. WPST–TV. Showing mobilrail system in use.

Connector strips should be laid out to provide one outlet for every 14 to 20 sq ft of studio space. This means that if pipe battens are used on 5-ft centers, pigtails should be spaced 3 or 4 ft apart. When provisions are made for color broadcast, the area for each outlet should be closer to the 14-ft spacing. In addition to this approximately one outlet in five or six should be a 50-amp circuit.

In addition to the overhead outlets, some provision must be made for floor units. General practice is to provide one duplex 20-amp wall receptacle for every 20 to 40 running feet of wall. Also provide half as many wall receptacles with a single 50-amp receptacle. This will take care of rear screen projectors, follow spots, wall and table lamps, fireplace, and other effects and provide current for the occasional floor spot or scoop when required. These receptacles should be provided with the same connectors as the overhead connector strips. For color telecast make all the wall outlets 50 amp.

LIGHTING-LOAD REQUIREMENTS

Note that although one 20-amp outlet is provided every 14 to 20 sq ft of studio space, the load requirement is not 120 to 170 watts/sq ft. Some of the outlets will feed 500-watt fresnels, some 750-watt scoops, and some will not be in use at all on many occasions. The recommended lighting-load requirement is 25 watts/sq ft of studio area. This value will provide sufficient current for a quality picture with a minimum fixture movement.

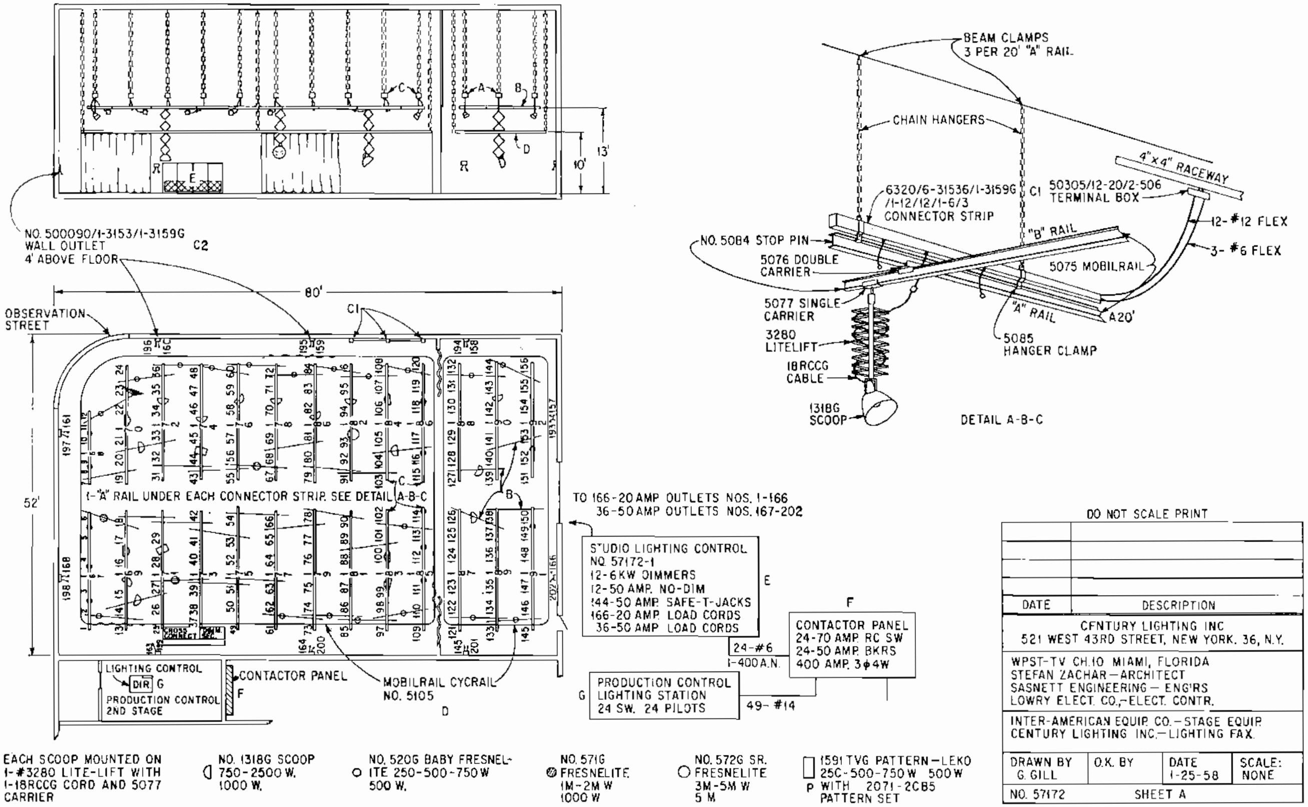

Fig. 3-4*b*. WPST–TV. Showing installation details.

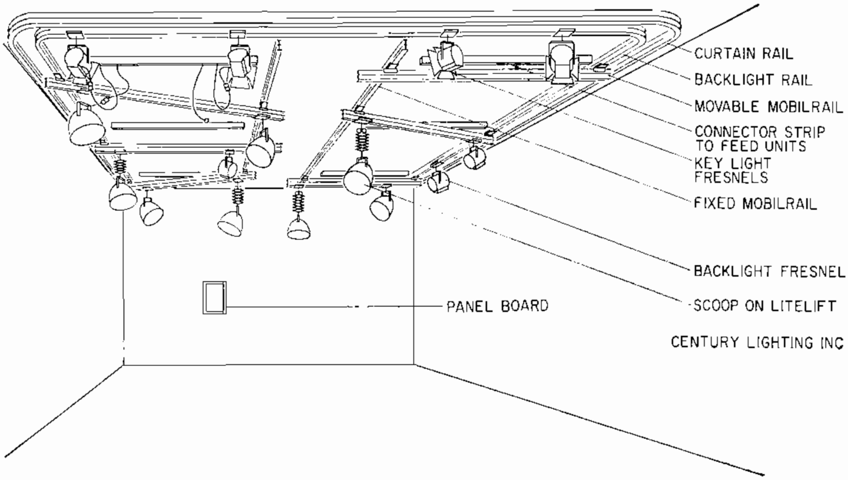

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FIG. 3-4*c*. Typical mobilrail layout for a small TV studio.

In figuring the feeder requirements, use 25 watts/sq ft. The minimum diversity factor to consider would be 80 per cent. Many engineers figure 100 per cent utilization. In the design of the air-conditioning system, a diversity factor of 50 to 60 per cent is used. Most engineers use 50 per cent or 12.5 watts/sq ft. This figure seems to satisfy most factors of good engineering practice, economics, and actor comfort.

In the design for color, provisions must be made for 80 to 100 watts/sq ft. The same factors for feeder utilization and air-conditioning apply: 80 to 100 per cent feeder utilization and 40 to 50 watts/sq ft for air-conditioning.

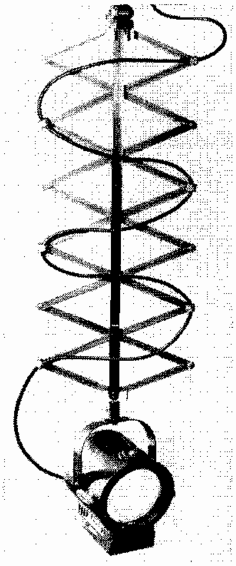

FIG. 3-5. Pantograph or light lift.

BUDGET

Listed in Table 3-1 are two typical schedules of connector strips and lighting equipment for monochrome and color. Scheduled is a 25- by 40-ft and a 40- by 60-ft studio.

Table 3-1. Cost Estimate for Lighting Equipment

Description	*Monochrome*	*Color*	*Monochrome*	*Color*
	25 by 40 ft		*40 by 60 ft*	
Connector strips and wall receptacles	$1,400	$ 1,600	$ 3,500	$ 3,900
Lighting instruments and accessories	$3,400	$ 5,100	$ 6,700	$10,500
Patch panel	$1,900	$ 2,100	$ 4,000	$ 4,500
Dimmer bank	$1,200	$ 2,000	$ 2,000	$ 3,700
Electronic dimming with presetting	$8,000	$14,000	$14,000	$20,000

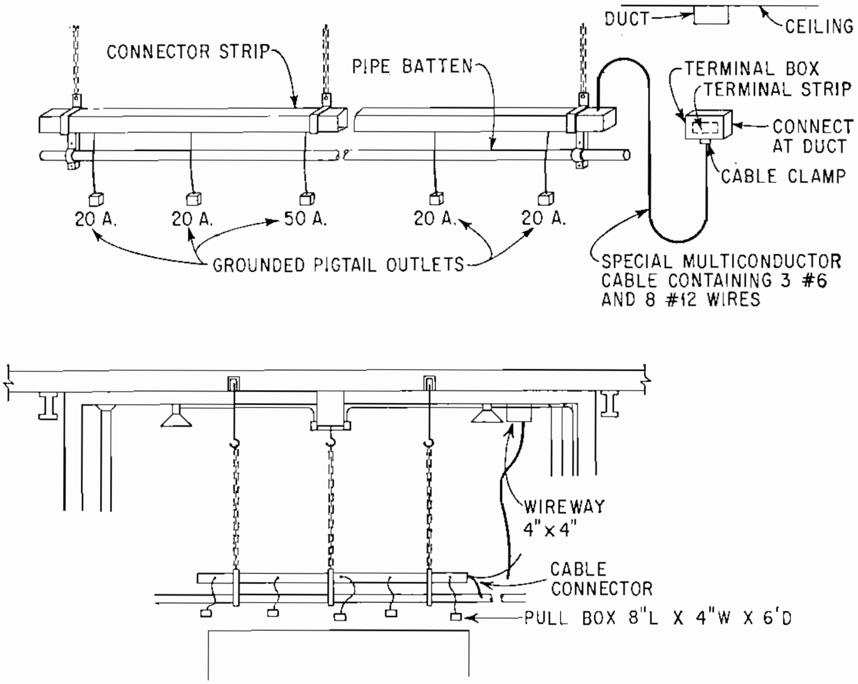

FIG. 3-6. Typical detail of connector strip installation.

Table 3-2. Electrical System for a 25- by 40-ft Studio [*]

(1,000 sq ft of studio area, 56 overhead and 7 wall circuits, 17.9 sq ft per overhead circuit)

	Quantity	
Description	*Black and white*	*Color*
20-ft connector strip: seven 3-ft pigtails, each with 20-amp capacity, terminating in three-pole, female pin connectors	8	
20-ft connector strip: seven 3-ft pigtails, six with 20- and one with 50-amp capacity, terminating in threc-pole female pin connectors		8
Note: Above type numbers refer to a three-wire, grounded system. To specify a two-wire, ungrounded system, change the type number from the 63 to the 62 series.		
Wall receptacle: double 20-amp three-pole pin connector	3	3
Wall receptable: single 50-amp three-pole pine connector	1	1
(Nos. 3046 and 3048 for equivalent two-pole units)		
Cyclorama rail: aluminum I-beam rail with snspension straps and 93 ball-bearing rollers and curtain hooks, ft	93	93
Switchboard: 72 load, circuit-breaker control panel (62- to 20- and 10- to 50-amp circuits)	1	1
Switchboard: patch panel with 72 load cords (62- to 20- and 10- to 50-amp)	1	1
39 control jacks, six group master preset switches. Plus:		
Dimmer bank: three 6-kw transformer interlocking dimmers, one master interlocking handle, three 50-amp primary breaker switches	1	
Dimmer bank: six 6-kw transformer interlocking dimmers, one master interlocking handle, six 50-amp primary breaker switches		1

[*] For information and prices about more advanced lighting control systems, refer to the separate heading entitled Control Systems.

Table 3-3. Equipment List for a 25- by 40-ft Studio

(Load power, watts/sq ft. Monochrome: 31. Color: 107)

	Quantity	
Description	*Black and white*	*Color*
3-in. 75- to 150-watt fresnelite	3	3
Two-way barn door for No. 523	3	3
6-in. 250- to 750-watt fresnelite	18	6
Four-way barn door for No. 520	10	3
8-in. 1,000- to 1,500-watt fresnelite	6	
Four-way barn door for No. 526	4	
8-in. 1,000- to 2,000-watt fresnelite		16
Four-way barn door for No. 571		8
12-in. 1,000- to 2,000-watt fresnelite		4
Four-way barn door for No. 572		2
16-in. 5,000-watt fresnelite		2
Four-way barn door for No. 576		2
18-in. 750- to 2,000-watt scoop	15	18
18-in. diffuser frame for No. 1318	15	18
6-in. 250- to 750-watt pattern projector with shutters and gobo slot	3	2
Gobo holder for above	3	2
Gobo slides for above – 6/set	3	2
8-in. 1,000- to 2,000-watt pattern projector with shutters and gobo slot		1
Gobo holder for above		1
Gobo slide for above – 6/set		1
6-in. 1,500-watt follow spot	1	1
6-ft striplight, 12-lamp unit with a 3-ft pigtail and three-pole male pin connector	2	
6-ft striplight, 12-lamp unit on three circuits with three pigtails at each end		2
12-ft extension light lift, support 12 to 15 lb	9	12
18-ft jumper, 12/3 cable, 20-amp pin connectors	9	12
24-in. three-legged castered stand, 5- to 8-ft extension	3	3
25-ft jumper, 12/3 cable, 20-amp pin connectors	3	3

Table 3-4. Electrical System for a 40- by 60-ft Studio [*]

(2,400 sq ft of studio area, 144 overhead and 9 wall circuits, 16.6 sq ft per overhead circuits)

	Quantity	
Description	*Black and white*	*Color*
18-ft connector strip: five 3-ft pigtails, each with 20-amp capacity, terminating in three-pole, female pin connectors	24	
18-ft connector strip: five 3-ft pigtails, four with 20- and one with 50-amp capacity, terminating in three-pole female pin connectors		24
Note: Above type numbers refer to a three-wire, grounded system. To specify a two-wire ungrounded system, change the type number from the 63 to the 62 series.		
Wall receptacle: double 20-amp three-pole pin connector	4	4
Wall receptacle: single 50-amp three-pole pin connector	1	1
(Nos. 3046 and 3048 for equivalent two-pole units)		
Cyclorama rail: aluminum I-beam rail with suspension straps and 148 ball-bearing rollers and curtain hooks, ft	148	148

[*] For information and prices about more advanced lighting control systems, refer to the separate heading entitled Control Systems.

Table 3-4. (*Continued*)

	Quantity	
	Black and white	*Color*
Switchboard: patch panel with 153 load cords (one hundred and thirty-four 20-amp and nineteen 50-amp), 144 control jacks, 12 3-position selector switches each with three 50-amp breaker switches, three sub-master relay switches, 36 pilot lights	1	1
Dimmer bank: six 6-kw transformer interlocking dimmers, one master interlocking handle, six 50-amp primary breaker switches	1	
Dimmer bank: twelve 6-kw transformer interlocking dimmers, one master interlocking handle, twelve 50-amp primary breaker switches		1

Table 3-5. Equipment List for a 40- by 60-ft Studio

(Load power, watts/sq ft. Monochrome: 24, color: 90)

	Quantity	
Description	*Black and white*	*Color*
3-in. 75- to 150-watt fresnelite	4	4
Two-way barn door for No. 523	4	4
6-in. 250- to 750-watt fresnelite	30	8
Four-way barn door for No. 520	16	5
8-in. 1,000- to 1,500-watt fresnelite	8	
Four-way barn door for No. 526	4	
8-in. 1,000- to 2,000-watt fresnelite		30
Four-way barn door for No. 571		16
12-in. 1,000- to 2,000-watt fresnelite	4	9
Four-way barn door for No. 572	2	5
16-in. 5,000-watt fresnelite		4
Four-way barn door for No. 576		4
18-in. 750- to 2,000-watt scoop	30	40
18-in. diffuser frame for No. 1318	30	40
6-in. 250- to 750-watt pattern projector with shutters and gobo slot	3	1
Gobo holder for above	3	1
Gobo slides for above – 6/set	3	1
8-in. 1,000- to 2,000-watt pattern projector with shutters and gobo slot	1	3
Gobo holder for above	1	3
Gobo slide for above – 6/set	1	3
6-in. 1,500-watt follow spot	1	
12-in. 3,000-watt follow spot	1	2
6-ft striplite, 12-lamp unit on three circuits, with three pigtails at each end		4
6-ft striplite, 12-lamp unit with a 3-ft pigtail and three-pole 20-amp pin connector	4	
12-ft extension light lift, support 12 to 15 lb	15	20
18-ft jumper, 12/3 cable, 20-amp pin connectors	15	20
24-in. three-legged castered stand, 5- to 8-ft extension	6	6
25-ft jumper, 12/3 cable, 20-amp pin connectors	6	6

LIGHTING CONTROL

In TV-studio-lighting practice, the multiplicity of scenes and fluidity of light movement require an ever-increasing number of lighting units and in turn an increasing number of dimmer-control circuits. The producer, director, and viewer are demanding and getting a more artistic lighting result. The planning groups are putting more modern control tools in the hands of the operating personnel. The lighting director and engineers are utilizing these facilities and are asking for more dimmers.

To achieve superior professional and artistic results as well as to get a competitive sales advantage, many studios use electronic control boards in their lighting systems. These boards include multiscene electronic dimming systems with ON-OFF and intensity memory and scene-to-scene fading. The savings in setup and rehearsal time together with the superior results warrant the consideration and use of these systems.

This emphasizes the importance of the lighting-control center. A simplified system must be provided for normal operations. Yet it must be flexible enough and advanced enough to provide artistic results and handle complicated shows. The lighting-control center has been called "the heart of the art."

This area of the facility requires careful study. Here one can spend $5 per load circuit for a circuit-breaker panel or $125 per load circuit for a multiscene preset electronic, magnetic amplifier or silicon-controlled rectifier control board. Fully automatic punch-card systems are now available at a cost of about 20 per cent over that of a 10-scene preset board in a large system.

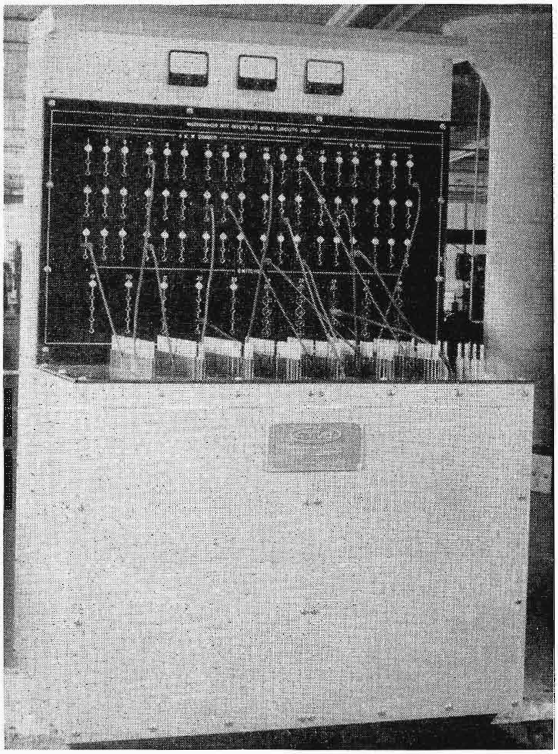

FIG. 3-7. Patch panel with retractable cords.

The lighting-control center should be designed so that maximum control can be exercised. Every light should be controlled singly or together with any other light or group of lights, and each light and each group should be adjustable to varying intensities desired by the lighting director. Lights should be able to be preset as to ON-OFF and intensity. Ultimately they should be able to be preset as to color, direction, and even movement. The industry still has far to go toward expanding yet simplifying the light-control center.

The importance of dimmers should not be underrated. They are essential for balancing light composition. Dimmers are useful in handling subtle time changes during a scene. Dimmers are important to increase or decrease light intensities in certain areas of a set to heighten dramatic intensity. They permit slow "bringing in" of set areas or people. Silhouette effects are artistically handled with dimmers. Many other special and intricate effects are accomplished with dimmers.

Since each lighting unit comes to the lighting-control center as a single circuit, some means of grouping lights by set area and function should be provided. Where circuit-breaker switches alone are used in a small studio, generally no means of grouping is provided. In a larger studio, breakers may be grouped and mastered. The most common system of grouping is the patch panel with retractable cords. In this system, each load circuit is represented by a cord and plug (similar to a telephone switchboard). Then four or six female receptacles are grouped together and controlled by dimmers or nondim contactors. A modified version of this is the wall-mounted nonretractable patch panel (Fig. 3-8). Another popular means of grouping lights is the rotary-switch panel. Here, each load circuit is represented by a rotary switch. The load can then be grouped into any one of 12 or 24 dimmer or nondim circuits.

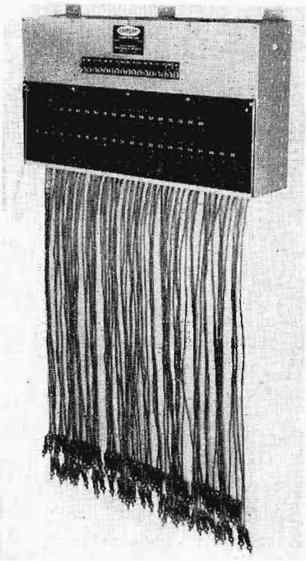

FIG. 3-8. Wall-mounted patch panel.

When circuit-breaker panels are provided, they should be located on the studio floor along a wall which will not be covered by scenery or within camera view. When a patch panel is used, it should be located on the studio floor for speed in setting and grouping lights during rehearsal. It is desirable to have a remotely located contactor panel to control the main control groups, i.e., one for each dimmer and one for each nondim section. One control station for the contactors should be placed at the dimmer board. A second station should be located in the control room. This way, during rehearsal, the patching and dimmer settings can be made by the electrician on the studio floor. During the show, if no changes in setup are required, the switch-

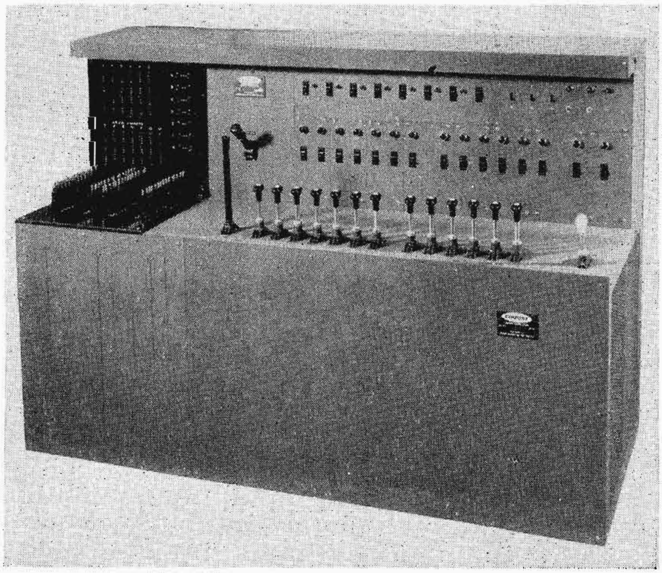

FIG. 3-9. Autotransformer dimmer board.

ing of lighting groups can be accomplished from the control room. The most commonly used dimmers are the 6,000-watt autotransformer (Fig. 3-9), the all-electronic thyratron tube (Fig. 3-10), and the magnetic amplifier (Fig. 3-11*a*). The autotransformer is a durable, efficient unit. It is generally provided with a mechanical-interlock handle. No presetting or memory is included. Contactors can be provided for remote on-off control. Generally one 6,000-watt dimmer is provided for each 6 to 10 lighting-load circuits.

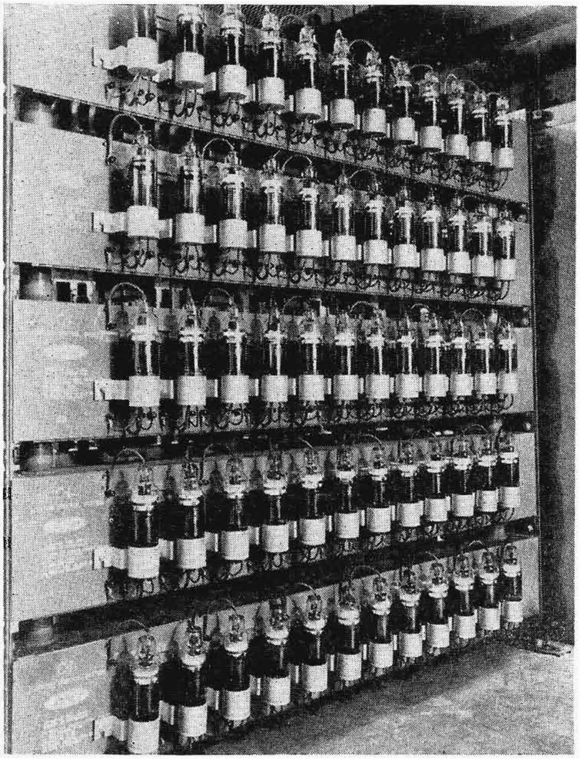

FIG. 3-10. Tube bank of thyratron dimmers.

The thyratron tube sparked the acceptance of the multiscene preset lighting-control board (Fig. 3-12). Ten-scene preset boards are in use in studios of all the major networks. They permit the operator always to be nine "light scenes" ahead of the action on camera. The lights are preset as to ON-OFF and intensity. Complete setup of lights can be instantly switched or slowly and subtly changed by the movement of one handle. Loading ratio of the tube is infinite (within its rated capacity), response is instantaneous, cross fading is linear, and maintenance excellent.

The magnetic amplifier also lends itself to presetting and remote operation. It is available in many capacities and has long life.

The silicon-controlled rectifier dimmer (Fig. 11*b* and *c*) is the newest member of the electronic dimmer group. When utilized as the heart of the dimmer circuit, the dimmer becomes small in size, light in weight, high in efficiency, cool in operation, and moderate in price. It will make obsolete the magnetic amplifier and thyratron-tube dimmer. The silicon-controlled rectifier dimmer is available in capacities of 2,500, 4,000, and 5,000 watts. It will soon be available in 6,000-, 8,000-, and 10,000-

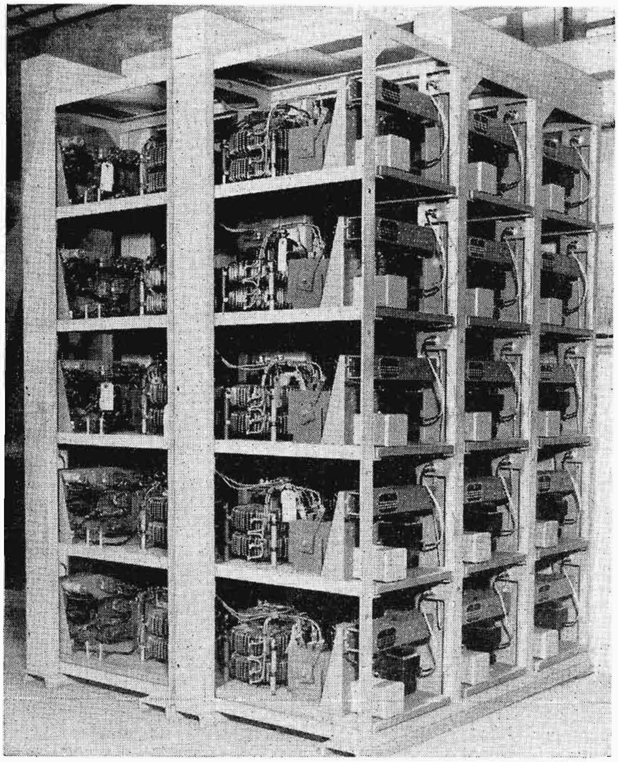

FIG. 3-11*a*. Magnetic amplifier dimmer bank.

watt capacities. As production of the rectifier increases, the price will decrease. It is hoped that the price will one day compete with the autotransformer dimmer.

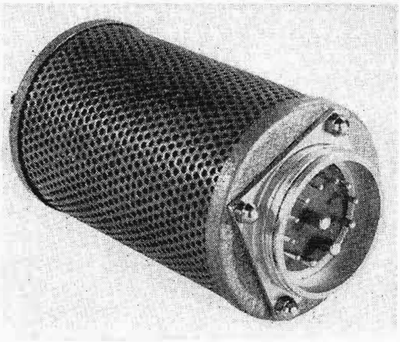

FIG. 3-11*b*. Silicon-controlled rectifier dimmer.

A great step forward in the automation of TV lighting is the Century Lighting development of "Punch" (Fig. 3-11*d*), the first all-automatic infinite preset system for control of light intensities. This system permits the lighting director to adjust the light intensities for each "scene," then automatically record them on a punch card. When the show is completely lighted, the cards are stacked in rotation and the operator fades or switches from one light scene to the next at any desired speed. The cards are fed into the binary memory system automatically.

Provisions are made to "override" the memory, skip cards, duplicate cards, black out, and repeat cue. This system completely eliminates all mechanical operations with the exception of setting up the proper lighting conditions for each scene or preset and the timing of each change or fade. This system allows more time for artistic perfection by providing more time during rehearsal for the proper setting of light and gives more "stage" time to the actors and director. "Punch" can be used with thyratron-tube dimmers, magnetic amplifiers, or silicon-controlled rectifier dimmers.

When preset memory systems for on-off control are provided, the control console can be placed in the control room, and the memory bank and the circuit breaker and contactor panels can be placed in any adjacent off-studio space. They should be sound-isolated from the studio.

When multiscene preset boards incorporating thyratron tubes, magnetic amplifiers, or silicon-controlled rectifiers are used, the light circuits go back to a patch panel located on the studio floor (or in a large studio on a balcony). The dimmers are located remotely. The control console and preset panel can be located in any convenient location, i.e., control room, etc.

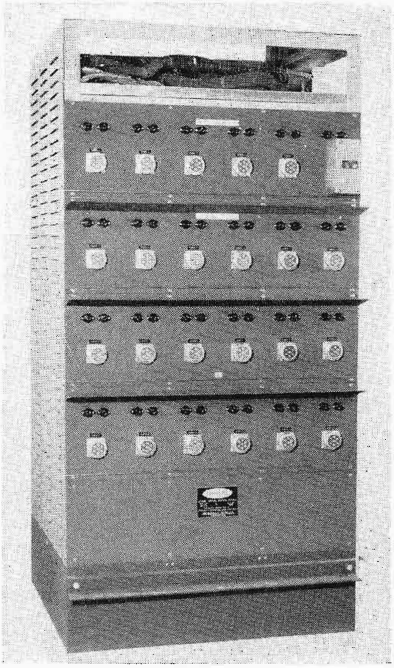

FIG. 3-11*c*. Silicon-controlled rectifier dimmer bank.

BUDGET PRICES FOR LIGHTING-CONTROL SYSTEMS

Note that these prices vary widely because of variations in size of systems, special features, and personal preferences of the designing engineers. They can be used as a guide. When designing for a particular studio, equipment manufacturers should be called in for more exact prices and recommendations.

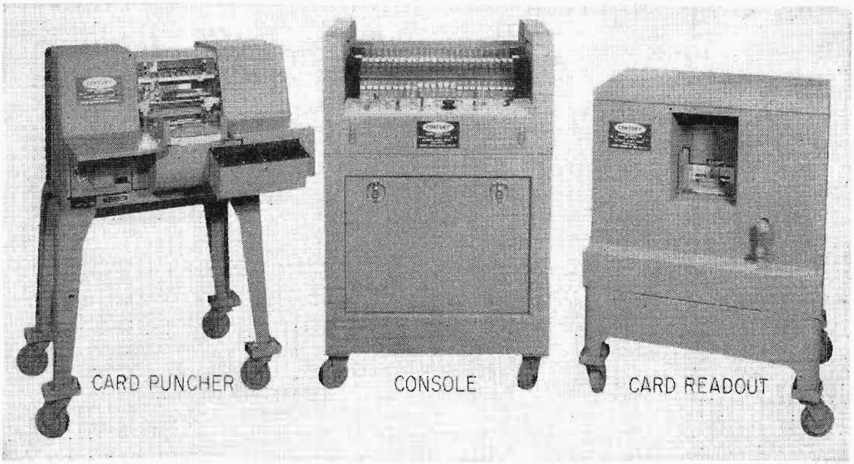

FIG. 3-11*d*. Fully automatic infinite preset system for controlling light intensities.

Circuit-breaker panel	$5–$8 per circuit
Patch panel, no dimmers	$20–$40 per circuit
Rotary-switch panel, no dimmers	$40–$60 per circuit
6,000-watt autotransformer dimmers mounted in a system	$250–$350 per circuit
10-scene preset dimmer board with 6,000-watt thyratron tubes, or 5,000-watt silicon-controlled rectifiers including patch panel	$700–$900 per dimmer crt.
10-scene preset dimmer board with 6,300-watt magnetic amplifier dimmers including patch panel	$750–$950 per dimmer crt.
2-scene preset dimmer board with 5,000-watt thyratron tube, 5,000-watt silicon-controlled rectifiers, or 6,300-watt magnetic amplifier dimmers	$350–$450 per dimmer
5-scene selector ON-OFF memory system	$80–$100 per load circuit

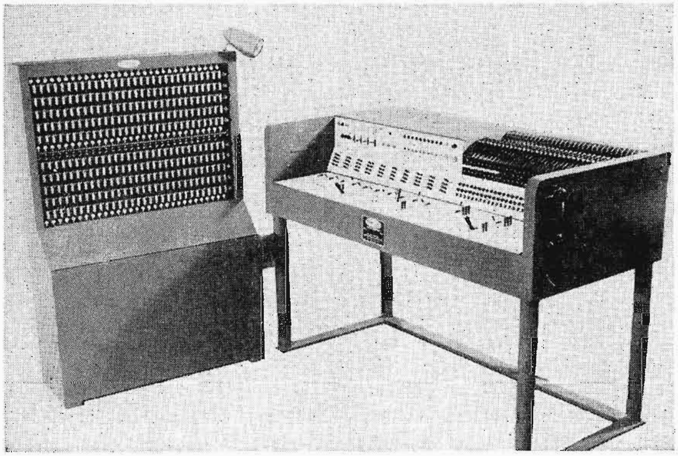

FIG. 3-12. 10-scene C-1 all-electronic control board.

Fully automatic infinite preset systems add 20 per cent to the cost of a large 10-scene preset system.

In some of the existing major studios, the complexity of the lighting is such that the dim and no-dim circuits are all in use and an operator is required to replug the patch panel during the show. To eliminate the need to replug, present reloading facilities have been designed by CBS Television and Century Lighting, Inc., by the use of mercury relays and programming boards.

Dimmers are receiving greater use in color-TV lighting work than in monochrome use. This is partially due to the selection of the top lighting directors (they are generally also the more artistic) to handle the color shows. Another factor is that the added cost of dimmers is small in relation to the over-all cost of the facility. Dimmers are good insurance for a quality picture.

TV LIGHTING PRACTICE

Rudy Bretz in his book "Techniques of Television Production" clearly points out the objectives which should always be kept in mind by lighting and engineering personnel. They call for understanding and cooperation among engineers, scenic designers, lighting directors, directors, and producers.

Directors have been learning about *f* stops, brightness contrasts, key lights, etc., to control the dramatic effect of the picture desired. For instance, if an actor is "shot" with a dark background and then the camera angle is switched to a light background, the actor's face will suddenly go dark as the contrast between his face and the background changes. It is almost impossible and generally impractical to correct with lights the shift in contrast. The knowledgeable director will try to keep his camera angles such as to get similar background brightness. His familiarity with the possibilities and limitations of lighting facilities will help him to avoid demanding the impossible. One of the finest procedures ever published to give direction to the new lighting director appears in "Television Broadcasting" by Howard A. Chinn of CBS Television Network, published by McGraw-Hill Book Company, Inc. We abstract here "General Lighting Techniques and Procedures" by permission of the author.

GENERAL LIGHTING TECHNIQUES AND PROCEDURES FOR MONOCHROME OPERATION

Lighting Practice 1. The standard lighting procedure should be (*a*) to establish first a uniform over-all base light which will ensure proper camera-operating conditions for technically good-quality pictures and (*b*) then to add carefully balanced effects light to obtain the desired artistic results.

Lighting Practice 2. Base light should be obtained from large-area diffuse sources arranged to produce a uniform illumination level throughout the set and from the viewpoint of all camera angles. The lighting-levels requirements will depend upon the camera tube. For example, with a type 5820 image-orthicon camera tube, a lighting intensity of 75 ± 10 lumens/sq ft, measured in a horizontal plane, is usually satisfactory. The vertical light intensity should be less than (½ to 1 times) the horizontal intensity.

Lighting Practice 3. To provide depth, to separate objects, and to add artistic interest to a picture, several types of effects lights should be added to the base light. Effects light may include key light, back light, modeling light, eye light, and special-effects light. In general these are best supplied from directional sources (usually incandescent) which can be conveniently adjusted in intensity, character, and coverage. Initial adjustments may be made with the aid of a photocell meter but final judgments should be made on a picture monitor.

Lighting Practice 4. Back light should be directed from the lowest possible rear angle with intensity between 1 and 1½ times the base-light level. The light meter should be pointed toward the source of back light for this measurement, and all other sources of light should be turned off. Vertical top light is not back light and is to be avoided.

Lighting Practice 5. Modeling light should be directed from a side-front position and can be adjusted in intensity just to produce shadows. In general the amount of light required will not exceed ½ to 1 times the base-light intensity.

Lighting Practice 6. Key light used to give the effect of a predominant source of light may be from 1 to 2 times the base-light level, with any base light from the same direction as the key light reduced accordingly.

Lighting Practice 7. Eye light can be added to brighten up a performer's eyes and to supplement the base light on close-ups. A small spotlight, mounted on the front of the camera and having an intensity of not more than ½ to 1 times the base light, is useful for this application.

Lighting Practice 8. Special lighting effects, such as spotlights, moonlight, and lights-out sequences, can be obtained by reducing the base light to approximately one-quarter its normal value, and any special-effects lights then adjusted to bring the total illumination level up to 1 or 1½ times the normal base-light intensity (light meter aimed at camera positions).

Lighting Practice 9. Effects light directed to backgrounds to create window and similar shadows should not exceed 1½ times the normal base light incident upon the background in question.

Lighting Practice 10. Self-luminous objects or areas such as exposed lamp bulbs, lanterns, and near lighted windows should not produce a light-meter reading in excess of ¾ to 1 times the normal base-light reading when the meter is held a few inches from the light source and directed toward it.

Lighting Practice 11. In monochrome transmission, incandescent light sources can be dimmed to one-quarter normal light intensity without impairing spectral response because of change in color temperature.

Lighting Practice 12. Lighting plans should be prepared in detail for all repetitive productions to ensure reproducibility of established lighting conditions.

By carefully following these procedures, it is almost impossible to get a bad picture.

The following adjustments should be made for lighting for color broadcasting: Base light plus key light should be increased from 100 to 300 to 400 ft-c. It is also essential that the entire background which is presented to the camera be evenly lighted. This is more critical in color work than in monochrome broadcast. Key and modeling light must be used from much flatter angles to minimize shadows under eyes, nose, and chin.

Pantographs are useful to eliminate mike boom shadow, to correct the angle of a motivating source, etc. In actual practice, generally about 50 per cent of the scoops and 40 per cent of the key lights are provided with pantographs. Pole slide carriers are generally used in studios equipped with a catwalk.

LIGHTING ROUTINE ON THE SHOW

Generally the show is in a studio where the lighting director has worked previously. Most of the equipment is more or less hanging in the right places owing to the physical limitations in most plants. The sets have to be in the same general locations such as along the studio walls, and it follows that the cameras, actors, and lights will also be in approximately the same areas as in the last show.

SYMBOL	COLOR PLAN
□	NO. 526 8" 1000–1500 W FRESNEL
☒	NO. 572 12" 1000–2000 W FRESNEL
⊡	NO. 576 16" 5000 W FRESNEL
◖	NO. 1315 16" 750–2500 W SCOOP
▷	NO. 1568 8" 1000–2000 W LEKO
	BLACK & WHITE PLAN
□	NO. 520 6" 250–750 W FRESNEL
☒	NO. 526 8" 1000–1500 W FRESNEL
⊡	NO. 572 12" 1000–2000 W FRESNEL
◖	NO. 1315 750–2500 W SCOOP
▷	NO. 1581 TV 4½" 250–750 W LEKO

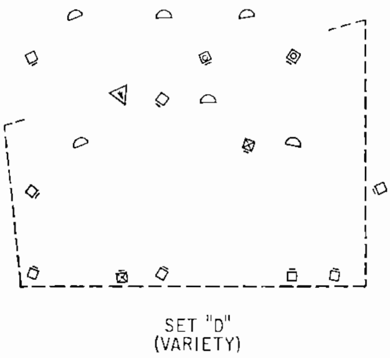

FIG. 3-13*a*. Layout of 1,000 sq ft area TV studio.

The lighting director meets with the scenic designer, director, and producer for a script review. Notes are made as to mood, time of day, special effects, etc. Camera angles and mike boom locations are plotted. Working from the floor plan, the lighting director then will lay out his lighting plan, keeping in mind what equipment is already hung. A few lights may not be accurately located until the sets are up and the mike booms brought in. Now the lighting director goes into the studio with 95 per cent of his lights plotted and most of them where he wants them.

Lights are now added or shifted by the electricians. After the sets are in place, the last few lights are decided upon and placed. Generally, the first lights set are used by the actors as work lights. While the actors continue their rehearsals, additional sets are being erected.

The lighting director starts lighting with "key light." This will be set at a level high enough for the camera to operate with a high signal-to-noise ratio. This is a departure from the old accepted practice of starting with base light and adding key, etc. (Note this change from Chinu's procedures.) By starting with key light, the lighting director can get a more artistic picture at lower foot-candle levels. Fill light is then added. Then pattern projectors, eye lights, and specials are added as required. Lights are all focused accurately, barn doors adjusted, and minor corrections carried out. While this is happening, the lighting director checks the light levels with a meter and the over-all result in the monitor. The monitor check is the one that really counts.

The electrician generally has the responsibility for grouping the lights at the patch panel and dimmer board. He also provides his own cue sheet, generally in his own fashion. On an extremely complicated show, the lighting director may lay out the patching and dimming control. For a color show, he will lay out the colors and select the cinemoids before setting up, so the electrician can be sure to have sufficient quantities on hand.

In lighting a simple "milk-run" show, the lighting director might not even prepare a light plot but simply direct the hanging and focusing of lights as the sets go up (Fig. 3-13).

CENTURY LIGHTING, INC. T. V. PLANNING AID

Set *A*, panel or small dramatic
B, dramatic *D*, variety
C, small variety, dramatic *E*, kitchen
F, news, interview, commercial *G*, weather, commercial

Studio Set Plans
Equipment List

Type	Description	Quantity													
		Black and White							Color						
		A	*B*	*C*	*D*	*E*	*F*	*G*	*A*	*B*	*C*	*D*	*E*	*F*	*G*
520	6-in. 250- to 750-watt fresnelite	4	4	3	8	3	2								
2570	Two-way barn door for No. 520	1			2										
2580	Four-way barn door for No. 520	1	2	1	2	1	1	1							
526	8-in. 1,000- to 1,500-watt fresnelite	3	4	4	2	3	1	2							
2571	Two-way barn door for No. 526	1				1									
2581	Four-way barn door for No. 526	2	2	2	1	1	1	1							
571	8-in. 1,000- to 2,000-watt fresnelite								4	4	3	8	3	3	2
2567	Two-way barn door for No. 571								1			2			
2585	Four-way barn door for No. 571								1	2	1	2	1	1	1
572	12-in. 1,000- to 2,000-watt fresnelite		2	2	2				3	4	4	2	3	1	2
2573	Two-way barn door for No. 572								1				1		
2583	Four-way barn door for No. 572		2	2	2				2	2	2	1	1	1	1
576	16-in. 5,000-watt fresnelite									2	2	2			
2559	Two-way barn door for No. 576														
2586	Four-way barn door for No. 576									2	2	2			
1318	18-in. 750- to 2,000-watt scoop	4	4	5	6	3	3	2	6	6	8	9	4	4	3
3236	18-in. diffuser frame for No. 1318	4	4	5	6	3	3	2	6	6	8	9	4	4	3
1542	12-in. 3-kw follow spot			1	1						2	2			
1591TV	6-in. 250- to 750-watt pattern projector		1	1	1		1								
1557TV	8-in. 1,000- to 2,000-watt pattern projector									1	1	1		1	
3286	12-ft extension light-lift pantograph	2	2	3	3	2	2	1	3	3	4	5	2	2	2
18RCC	18-ft jumper cable for No. 3286	2	2	3	3	2	2	1	3	3	4	5	2	2	2
3216	24-in. castered, 5- to 8-ft extension stand	1	1	1	2	1	1	1	1	1	2	2	1	1	1
25RCC	25-ft extension cable	1	1	1	2	1	1	1	1	1	2	2	1	1	1

NOTES: 1. Type numbers are given for a two-wire ungrounded system. To specify a three-wire grounded system add G to the type number.

2. Portable floor stands are used on all sets and are listed above but are not shown in the diagrams. Additional fixtures for use with these stands are included in above list but are also not shown in diagram.

FIG. 3-13*b*. Equipment list for typical set areas.

There is no universal plan for setting lights in the studio so that they can be used for all situations without being moved. There is not enough ceiling space for that, and probably no one could afford it. However, in most studios, the majority of the lights will remain where set from one show to the next. For instance, most of the back lights will remain where they are, though some may have to be added where wings are set. This generally follows with the base lights, key lights, etc.

After a show is over, the light plot, plugging plot, and cue sheets are generally discarded, since the conditions for that show (script, director, scenic designer, lighting director, and studio) will almost never repeat themselves. For repeat shows, this information is recorded and kept.

Generally, very little consideration is given to the lighting for kinescope recording. Since live shows demand a high standard of lighting, the producer cannot afford the compromise of the flat light most desirable for kinescope recording. The range of video tape is well within the range of the camera tube. Therefore no special adjustments have to be made for VTR.

Some additional proceedures and practices are:

1. The practical brightness contrast range for operational use is considered to be 30 or 40 to 1 even though "the book" says 20 to 1; *f* stops between *f*-8 and *f*-16 are generally used. This gives good depth of focus. As the *f* stop is decreased, depth of focus decreases and the background loses sharpness. As the *f* stop is decreased, lower light levels should be used. Put differently, where only low levels of light are available, reduce the *f* stop, being careful to remember that depth of focus will also be reduced.

2. When more light is required on an actor's face, it is simpler to reduce the intensity of the background. This will improve the contrast between the actor and the background and create the same effect as more light.

3. Whenever foot-candle levels are given, they are for incident light, i.e., with the light meter turned toward the camera tube.

4. Lighting adjustments should normally be checked with the video-control operator. Often carefully created lighting effects are nullified by a video shader who is unaware of what a production crew is attempting to create. Coordination between production and video personnel saves considerable time and often results in otherwise unobtainable effects.

5. Barn doors should be used on all back and side lights to prevent glare into the camera lens. Lens hoods are essential for complete camera mobility without the danger of lens flare.

6. Pattern projectors are often used to make unnoticed a difficult mike boom or subject shadow.

7. Endeavor to keep the subjects as far away from the background as space permits. This reduces shadows on backgrounds and aids the back lights to provide desired depth to the picture.

8. Specific personnel should be responsible for lighting and lighting-facilities maintenance. A light meter should always be available.

9. Time should be allowed for the proper lighting of a show.

10. A safe inexpensive picture can always be obtained by simply directing 100 ft-c of flat light on the set. However, this is a dull picture, which will tend to lose audience interest.

Where the type 7038 vidicon tube is used, 100 ft-c must be provided for card lighting. Where movement takes place, 200 to 300 ft-c are necessary to help overcome "lag."

It is important to spend as much time training personnel as possible. Every dollar spent for lighting training will come back manyfold. A definite lighting training program should be started before moving into any new studio. A continuing educational program should be planned and kept in operation always. As new lighting instruments and techniques become known, all operation and artistic personnel should be made aware of these developments. Good lighting techniques should become SOP for all.

LIGHTING INSTRUMENTS

The range of available TV lighting instruments is large and varied. Each unit has its usefulness and is another tool in the hands of the skilled lighting director. The tools should be understood and used properly. It is recommended that new personnel be given the opportunity to examine, light, check, and study each type of unit in the studio.

A description of each type of fixture follows.

The Scoop (Figs. 3-14*a* and *b*)

This wide-angle floodlight is one of the two most used lighting instruments in TV. The other is the fresnel. It is used for base and fill light. The scoop provides a great deal of soft diffuse light in a wide beam from a lightweight compact instrument (Fig. 3-14*a*). The finish is matte-finish Alzak. Accessories include glass cloth diffusers, clamps, cinemoid color media, and light lifts.

Scoop sizes and wattages are:

Inches	*Watts*
10	250–400
14	300–500
16	750–1,000–1,500–2,000–2,500
18	750–1,000–1,500–2,000–2,500

FIG. 3-14*a*. 18-in. 750- to 2,500-watt scoop.

The 2,500-watt lamp tends to overheat the unit and is not recommended except for short periods of time.

For monochrome broadcasting, the 1,000-watt lamp is most often used. In studios with very high pipes sometimes 1,500-watt lamps are installed. In color telecasting, the 1,500- and 2,000-watt lamps are used.

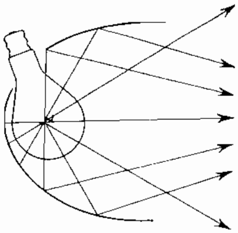

FIG. 3-14*b*. Optics of the scoop.

The Fresnel (Figs. 3-15*a*, *b*, and *c*)

The second most used unit in TV is the fresnel spotlight. Gradually this versatile unit is becoming the most important single lighting instrument. The fresnel provides a variable focus or beam spread. The field is smooth, even, and soft edged. The fresnel on flood focus is the most efficient of all the spotlights (Fig. 3-15*b*). It is available in a large variety of sizes and wattages as listed below. Accessories include barn doors, diffusing screens, cookies, color media, and light lifts.

A variety of lenses are available for wide-angle or narrow-beam distribution. Rectangular beam spreads are available.

Units are manufactured with rear access for relamping without disturbing barn-door setting.

Some units are equipped with "pole-op" provisions so that the fresnels can be "spotted-down" or "flooded" from the floor. "Sticky-joint" units are available which can be tilted and panned from the floor.

The units being offered for sale today by the major manufacturers have been specifically designed for TV use. The lenses have black ceramic risers to reduce spill light. They have been designed to give specific distributions and to work effectively with barn boors.

Century Lighting has designed a system for remote-control operation (Fig. 3-15*c*). This system includes remote control raise-lower, pan, tilt, spot-flood, and mechanical bright-dim. The system is expensive, and it is difficult to justify the cost of installation. However, in areas of high rent, high labor cost, and intensive studio use, this system can justify its cost.

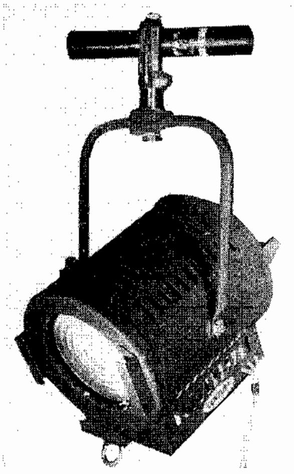

FIG. 3-15*a*. 12-in. 1,000- to 2,000-watt fresnel with "pole-op," rear access, "sticky-joint."

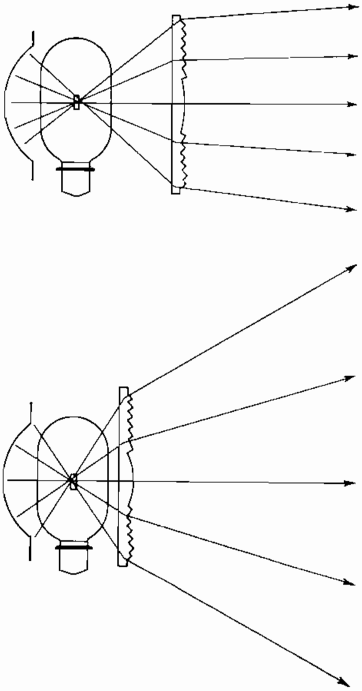

FIG. 3-15*b*. Optics of the fresnel spot.

In black-and-white broadcasts, the 6-in. 500-watt unit is generally used for back light, with the 6-in. 750-watt and 8-in. 1,000-watt units doing the key lighting.

When telecasting in color, the back lights are generally the 8-in. 1,000- to 2,000-watt units with 1,000-watt lamps. For key lighting, the 8- and 12-in. 1,000- to 2,000-watt units are necessary with some 16-in. 5,000-watt units used for high key.

Lens, in.	*Wattage*	*Beam spreads, deg*
3	75–100–125–150	15–40
6	250–500–750	15–60
8	1,000–1,500	15–45
8	1,000–2,000	15–60
10	1,000–2,000	15–60
12	1,000–2,000	15–70
14	3,000–5,000	15–45
16	3,000–5,000	15–70
20	10,000	15–60

The 6-, 8-, 12-, and 14-in. units are also available with lenses which give a rectangular soft-edge distribution.

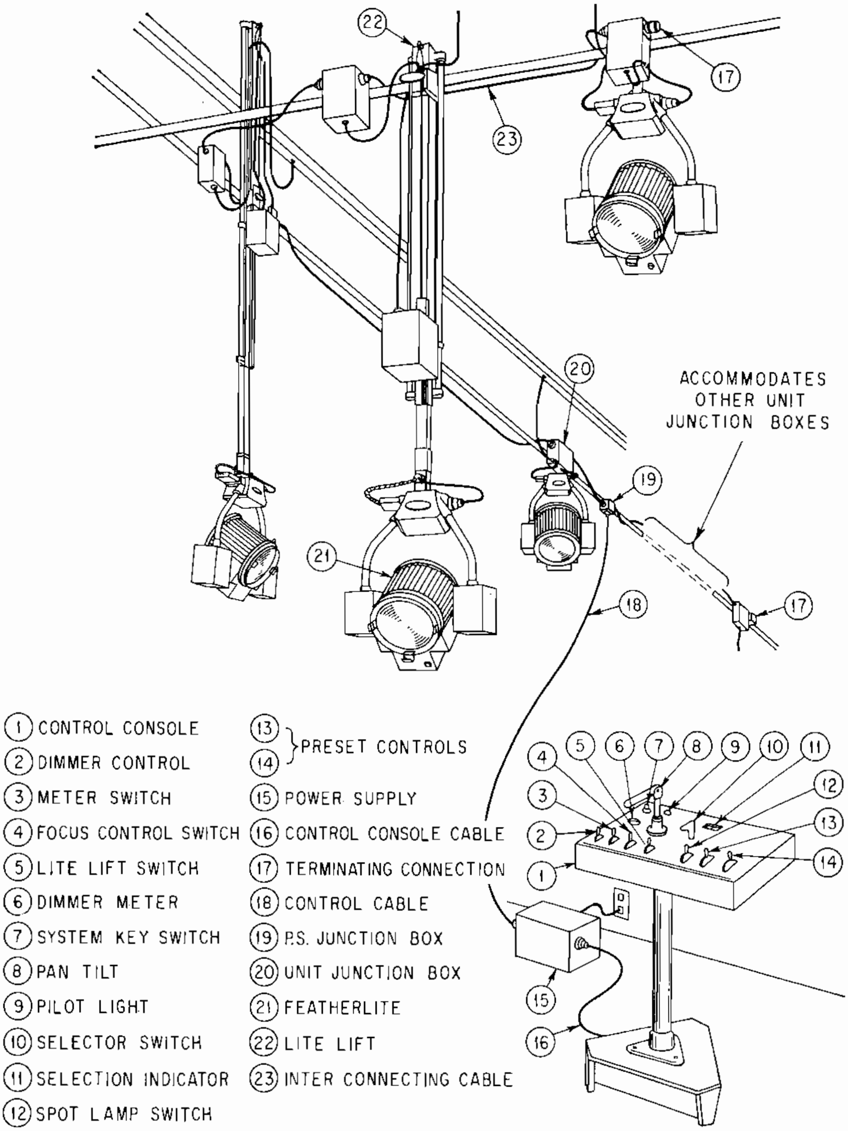

Fig. 3-15*c*. Remote-control fresnel.

Pattern Projectors (Lekos) (Figs. 3-16*a*, *b*, and *c*)

This ellipsoidal reflector spotlight (Fig. 3-16*a*) has built-in framing shutters for giving rectilinear shapes to a round beam. A built-in gobo slot permits the use of a wide variety of pattern effects (Fig. 3-16*c*) to be projected onto a background. The efficiency is as high as 40 per cent. The beam edge can be hard or soft depending on whether the lens is in or out of focus.

Fig. 3-16*a*. 6-in. 750-watt pattern projector Leko.

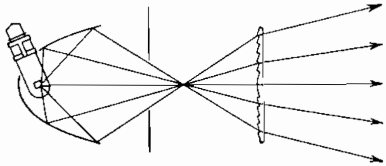

Fig. 3-16*b*. Optics for the pattern projector.

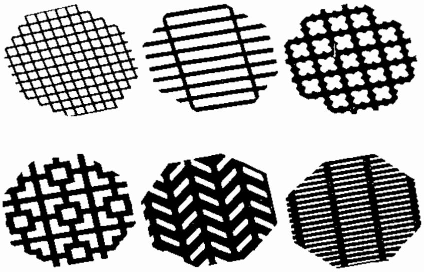

Fig. 3-16*c*. Gobos for insertion in pattern projectors.

Pattern projectors are also used as slash lights and for projecting circles, squares or rectangles on floors or walls.

The 6-in. 750-watt units are most used for monochrome work. The 1,000- to 2,000- and even 3,000-watt units are necessary for color work.

Lens, in.	*Wattage*	*Beam spread, deg*
4½	250–500	50
6	250–500–750	40
8	250–500–750	30
6	1,000–1,500–2,000	60
8	1,000–1,500–2,000	40
6	3,000	60

Reflector Lamp Banks

This unit consists of a square or rectangular sheet-metal or cast pan equipped with 4 to 12 medium screw sockets, yoke, clamp, and lead. The sockets take 150- to 300-watt reflector (R) or 150-watt projector (PAR) lamps. These lamps have a long (2,000-hr) life and are available in spot or floor distribution. Their low cost and long life made them useful in early television. As the art of TV lighting advanced, a higher degree of control of distribution became necessary, and the reflector lamp bank is disappearing in favor of scoops and fresnels. The inability to barn-door the bank, the inability to change the spread of the unit, and the bulk of the unit all contributed to its demise.

Short life, high-output 375-watt photoflood lamps are sometimes used for a very short scene where little or no space is available. They are sometimes used on remotes. A word of caution is appropriate to their use. When the filament fails, it sometimes strikes the glass lamp jacket and causes it to shatter. Therefore, if photoflood lamps are used, a protective screen should be used in front of them. Some studios discard them after they have burned for 4 hr of their rated 6-hr life.

The Follow Spot (Fig. 3-17)

For variety shows, the follow spot still retains a certain dramatic quality that is irreplaceable. Arc lights have been used until very recently. Their disadvantage has been color and flicker. Recently 3,000- and 5,000-watt (Fig. 3-17) narrow-beam high-intensity follow spots were placed on the market. These are replacing the arc for network variety shows. The units have built-in iris, shutters, blowers, stands, and "chorus line" spread lenses. For black-and-white shows the 5-in. 1,500-watt unit is popular. Sizes and wattages are:

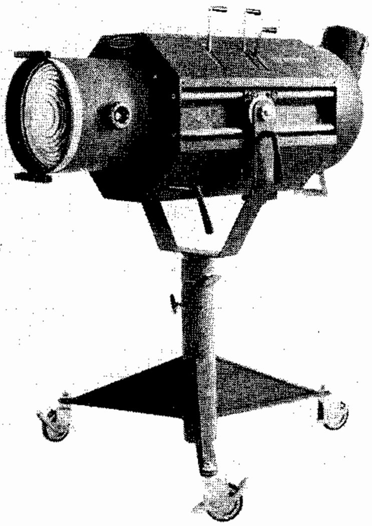

FIG. 3-17. 5,000-watt follow spot.

Inches	*Wattage*
8	750
5	1,500
6	1,000
8	1,000–1,500–2,000
12	3,000
12	5,000

The Strip Light (Fig. 3-18)

The strip light is a wireway with reflectors and sockets mounted in a sheet-metal housing. Generally the reflectors alternate between specular and matte finish, matte for the near throw and specular for the far projection. They are used to light eyes, backings, windows, etc.

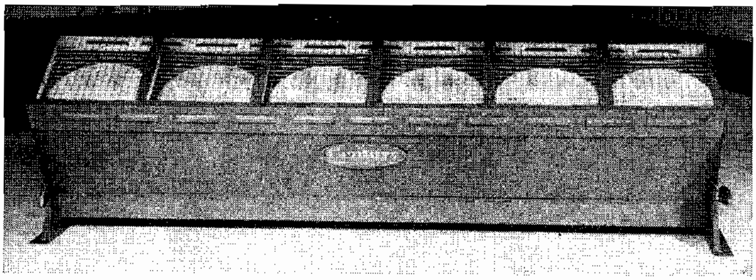

FIG. 3-18. Strip light with specular-finish reflectors.

The Punch Scoop

This unit has the same general characteristics as the scoop, except that it has a narrower beam of higher intensity. The beam spread can be varied slightly. In theatre studios, the punch scoop is used on the balcony front. The new larger unit is finding many specialized uses in color-television work. Punch-scoop sizes and wattages are 14-in., 750- to 1,000-watt size and 30-in., 3,000- to 5,000-watt size hot spot. The beam spread is 40° in spot focus and 100° in flood focus.

The Rear Screen Projector

This is an effective instrument for projecting scenic effects on a background. Placed behind a translucent screen, it throws the image of a slide on the screen. Care must be taken to keep the foreground lighting at as low a level as possible. Light falling on the screen should be kept to a practical minimum.

Rear screen projectors are available in wattages of 2,000, 2,100, 3,000, and 5,000. The one most frequently used is the 2,100-watt 60-volt unit. Many are equipped with magazine loading for 70 slides or drum loading for 5 slides. The RP's deliver between 4,000 and 6,000 screen lumens. Some studios have used carbon-arc RP's. These units, because of the point light source and high amperage, deliver sharp resolution and a high quantity of light to the scene. The color should be filtered for color-television use. The size, noise, and operation problems limit the popularity of the arc. For motion-picture clips, the arc is very popular.

The maximum effective spread for RP's is 8 ft in a 10-ft throw. Century Lighting has developed a 5,000-watt unit that gives a 15-ft spread in a 10-ft throw but has some distortion in the corners.

The Fluorescent Bank

The fluorescent bank, so popular in the earlier days of television, is gradually disappearing from the studio. The older camera tubes required 600 to 1,000 ft-c, and the highly efficient fluorescent lamps easily achieved these high levels. As the tubes became more sensitive and the art of lighting improved, the fluorescent bank became obsolete.

Other factors leading to obsolescence of the fluorescent bank were its bulk and consequent difficulty of moving or adjusting the unit, the noise factor of the ballasts, the inability to control its intensity or spread at the unit, and the inability to dim without complicated circuitry.

The Lighting "Igloo" or "Tent"

To light highly specular objects such as a watch, silverware, or a car, the ideal method is to surround the object with soft diffuse light and punch through with one single high-wattage spot. The "igloo" or "tent" consists of screen, gauze, or muslin surrounding the object. The tent is then lighted from all sides with scoops, etc., till it literally glows. One hole is cut into the tent for the camera, and one for the high-wattage spot. The resultant quality of light is excellent.

EQUIPMENT

Color-value Wall

A recent development in lighting is the color-value wall. This consists of a series of fluorescent and incandescent lamps spaced behind a translucent plastic diffusing screen. The lamps are on four-color circuits and are controlled by dimmers. By means of the additive method of color mixing, any color background can be obtained. Also any tone or tint of white light can be mixed. The color-value wall takes advantage of the phenomenon of "simultaneous contrast," and if the background color is changed, the foreground can be made to shift. Many other uses of this unit will be discovered as it gains wider usage.

The screen is available in sizes up to 45 by 85 ft. Lamp spacing can be as close as 16 in. per lamp per color in a 14-in. depth.

Lamp Replacement

The practice generally is to make a quick visual check of the lamps before use. Lamps which are dark and which look as if they have been burning for a long time should be replaced and discarded. For insurance, some lighting directors double-hang all important key lights, particularly in dramatic shows.

A method of extending lamp life is to bring the lights up on the dimmer rather than the full switch-on procedure. "Dimming-on" eliminates the initial surge of current which causes the filament to fail at its weakest spot. Most often a lamp failure occurs when the lamp is switched on rather than when it is burning.

To increase the amount of light available in existing studios without providing completely new facilities, some studios have devised a specialized practice. They operate 110-volt lamps on 120-volt service. This increases the light 30 per cent, decreases the lamp life 70 per cent, and increases the current consumption 15 per cent. This will give a studio a 30 per cent increase in light levels and may be the method used to go to color from black and white without greatly increasing studio lighting facilities.

LIGHTING-CONTROL-SYSTEM TERMINOLOGY

BOARD: The general term applied to a control board or switchboard. The various types are discussed in a later section of this chapter.

CONSOLE: A compact control face resembling an organ console in terms of size and arrangement of parts, generally placed so that the operator can see the studio.

DIMMER: A means of reducing the current or voltage in a circuit and thereby the intensity of light given off by the lamp in an instrument. It can be had in five general types: the resistance dimmer, the autotransformer, the magnetic amplifier, electronic tube, and the silicon-controlled rectifier. This is the most essential element in a switchboard. The dimmer is connected in series with the lamp, generally on the neutral side so that the current must trace through the lamp first, although with a cross-connecting or interplugging type of board it can be connected on the hot side and equipped with a disconnect, or low-end, limit switch.

EXTENDED OR FOREIGN CONTROL: A single-throw push-button switch on the end of a long lead which can close or open the grand master contractor pilot from a remote point.

FADER: A means of blending a lighting effect from one set of dimmer readings to another, manually or by automatic timer.

INDEPENDENT: Any circuit which is routed directly from the feed past the master or submaster so as to leave a circuit hot even when the master is thrown. This sometimes refers also to an undimmed circuit pocket or a constant potential circuit.

INTERCONNECTING: The ability to connect any load circuit to any line or control circuit by means of an interplugging or cross-connecting apparatus permits the grouping of widely separated instruments on adjacent, easily handled controls. The ordinary portable board is essentially of the interconnecting type. In permanent installations, a cross-connecting panel is installed. Generally the dimmers feed vertical bus bars and the load circuits are connected to horizontal bars which run across the face of the dimmer bars, forming a cross grid separated by proper insulating space. The connection can be made at any juncture by means of a plug. This is a cross-metering panel. The simplest form is the telephone-switchboard type using a jumper between the various line and load pockets.

INTERLOCKING: The individual dimmer handles can be twisted to drop a plunger into a slotted cam mounted rigidly on a shaft, which is connected solidly to the master interlocking handles.

MASTER CONTROL: The means for grouping a number of individual controls under a master switch or dimmer. Most boards have submaster control for each section with master control over each submaster. Most master switches are of the double-throw type which permits independent operation on the upthrow and grand-master operation on the downthrow.

PRESET: Any switch or dimmer arrangement which permits predetermining the lighting effect for a following scene or scenes, previous to its use, even while the circuit is in operation during a scene.

By the use of a contactor switch for each individual control unit, the routing of the current to the pilot can be controlled through any one of five or ten master preset switches. The same number of small toggle switches under each control unit can be thrown to determine in which of the scenes the circuit will be used. This is valuable only for presentation houses, where intensity balance is not important.

Preset dimming, however, enables the operator to anticipate a number of group actions. A fading mechanism generally blending from one hot feed to another, preset 1 to 2, can change the light effect proportionally from one setup to another. Some circuits go up; others go down; some remain constant with one movement. This requires a double- or multiple-dimmer control for each circuit. It is primarily practical only with remotely controlled dimmers where there are a number of intensity controllers associated with each individual circuit. This system is particularly useful in handling the complications of sunset effects.

Eventually, it is desirable for all switchboards where a smooth flow of lighting effect is created by more instruments than the operator can handle effectively with his two hands.

SETUP: A definite interconnecting arrangement between load circuits and feed pockets. Sometimes this is extended to include the switch arrangements and dimmer readings for a scene.

PRESET PILE ON: The ability to add one preset on top of the other; i.e., while the operator is in preset 4, he can add or "pile on" preset 6 (or any other preset or presets) on top of preset 4. The higher dimmer reading always takes over.

PRESET RELOADING: Consists of a system using mercury relays and programming cards located between the male plugs and female receptacles in the patch panel. This permits intensive loading of dimmers without replugging the patch panel.

CROSS-CONNECT MULTIPLIERS: These are devices to permit the operator to plug two load cords into one female receptacle in the patch panel. Similar to a "two-fer."

LANGUAGE OF LIGHTING

HIGH-KEY LIGHTING: A type of lighting which, applied to a scene, results in a picture having gradations falling primarily between gray and white; dark grays and blacks are present but in very limited areas.

LOW-KEY LIGHTING: A type of lighting which, applied to a scene, results in a picture having gradations from middle gray to black with comparatively limited areas of light grays and whites.

KEY LIGHT: The apparent principal source of directional illumination falling upon a subject or area.

BASE LIGHT: Uniform, diffuse illumination, approaching a shadowless condition, sufficient for a television picture of technical acceptability and which can be supplemented by other lighting.

FILL LIGHT: Supplementary illumination to reduce shadow or contrast range.

Cross Light: Equal illumination in front of the subject from two directions at substantially equal and opposite angles with the optical axis of the camera and a horizontal plane.

Back Light: Illumination from behind the subject in a direction substantially parallel to a vertical plane through the optical axis of the camera.

Side Back Light: Illumination from behind the subject in a direction not parallel to a vertical plane through the optical axis of the camera.

Eye Light: Illumination on a person to produce a specular reflection from the eyes (and teeth) without adding a significant increase in light to the subject.

Set Light: Separate illumination of background or set other than that provided for principal subjects or areas which may be composed of items 3 to 8 above.

(Copies are available from the SMPTE.)

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Part 4

MAGNETIC RECORDING ON DISC AND TAPE

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The material presented in this part is essentially a review of magnetic recording practices and the reasons for some of them. It is gathered from the many available sources and compiled into a general guide for the operating, maintenance, and installation engineer. While it may not answer specific questions, perhaps it will give an over-all picture that will help the engineer determine the answer he requires.

THEORY OF MAGNETIC RECORDING

The basic theory of magnetic recording is relatively simple. A magnetic material is moved through the field of a magnet, and the varying currents in the magnet are recorded on the material as varying degrees of magnetization. The magnetic material may be in the form of wire, tape, oxide-coated tape, oxide-coated discs, cylinders, etc. This discussion will be confined to oxide-coated discs and tape.

The magnet is usually called a "head" and consists of magnetically "soft" iron structures, known as "pole pieces," wound with coils of wire through which flows the signal current. This current generates the magnetomotive force which is conveyed to the magnetically "hard" recording medium by the pole pieces.

To reproduce the signal, the material is moved over the poles of a similar head and the magnetic impulses in the material generate a varying voltage in the coil which is then raised to the required level by a suitable amplifier.

The material which is magnetized consists of a nonmagnetic base which supplies the strength and an iron oxide coating which furnishes the magnetic properties. For tape recording, the base may be of paper, acetate, or polyester (mylar). For disc recording, the iron oxide particles are held to an aluminum plate by a binder material.

Bias

For the same reason that a vacuum tube must be biased for proper operation, the recording head of a tape recorder must also be biased for operation without excessive distortion. If the tape is biased with a steady d-c magnetic field, the audio magnetization will vary about this fixed point rather than zero. This is similar to a d-c bias voltage on a tube. Although this method corrects the distortion problem, the tape (where no signal is recorded) is left in a magnetized condition. Unfortunately, a magnetized tape is noisier than an unmagnetized one. In fact, the signal-to-noise ratio is degraded at least 10 db. Therefore, d-c bias has become obsolete, except in some battery-operated portable tape recorders.

To overcome this problem, it has become standard practice to use an a-c bias with the frequency sufficiently high to avoid being recorded on the tape. This leaves the tape in an unmagnetized condition when no audio modulation is being applied and correspondingly quieter. This bias frequency is usually selected to be five times the upper frequency limit of the recorder to prevent any beat between it and the harmonics of the audio signal. This is usually called supersonic bias and is in the 60- to 100-kc range. The current through the recording coil is always many times as great as that of the signal being recorded. Using the correct value of bias current is very important, for this affects the frequency response, distortion, and signal-to-noise characteristics of the recording.

A bias value that is too low may result in high distortion and a low signal-to-noise ratio, while too high a value causes a loss of high-frequency response (due to partial erasure). This adjustment can be readily made on a professional machine which has separate recording and playback heads and amplifiers. The best adjustment is made by recording a low-level tone in the range of 400 to 1,000 cycles and gradually increasing the bias current to the point of maximum reproduced signal. Further increase in bias will reduce the reproduced signal. The best adjustment is somewhere between the maximum signal and the point of 1-db reduction on the higher bias side of the curve. Machines which do not have simultaneous playback while recording can be adjusted in a similar manner by repeated recording and playback tests.

Erase

When the usefulness of the recording is over, it is general practice to erase the signal so that the tape or disc can be reused. Both d-c and a-c methods are possible, but the a-c method is almost always used. In a-c erasing, the tape or disc is subjected to an a-c magnetic field of decreasing intensity, caused either by an erase head preceding the recording head or by a large magnet powered from an a-c power line. The latter is used for the bulk erasure of a tape in one operation.

With either method of a-c erasure, it is essential that the first cycle or two be sufficient to saturate the magnetic material for complete erasure. Thereafter, the amplitude of the erasing field should decrease in intensity until the magnetic medium is at zero magnetization. When passing the tape or disc over the erase head while recording, it is necessary that the erase voltage variation (and resulting magnetic field) be reasonably symmetrical, or the tape will be left with some residual magnetization and the noise level increased. Many recorders have a noise-balance adjustment which either balances the output of the push-pull oscillator or neutralizes the effects of unbalance or leakage currents.

Usually a common high-frequency oscillator supplies the current for both erase and bias functions. Since the bias current is considerably less than the erase current, a portion of the erase current is coupled to the recording head. Some professional machines have metering provisions to adjust the proper erase and bias current. It is essential that the erase current be properly adjusted before adjusting bias, since later erase-current adjustments will affect the bias. Bias adjustments have no effect on the erase circuit.

Further details on magnetic recording theory can be obtained from some tape-recorder instruction manuals and from reference books, such as "Elements of Magnetic Tape Recording" by N. M. Haynes.

COMPONENTS OF MAGNETIC RECORDER/REPRODUCERS

Transport Mechanism

The purpose of this unit is to move the magnetic material across the erase, record, and reproduce heads. In a reel-to-reel mechanism this involves winding the tape from one reel to the other, with provision for running at accelerated speeds in either direction to provide fast-forward and rewinding. When the tape is moved in the recording or playback modes, the speed must be very stable to prevent flutter and wow. The starting time should be very short to allow close cueing, and the tape speed should be very constant to allow close timing of the program material and the correct pitch. During all functions, the tape must be handled gently to prevent stretching or breaking.

Reel-to-reel Type

The best known design of a reel-to-reel mechanism, which accomplishes the above requirements, has three motors. A typical reel-to-reel machine is shown in Fig. 4-1.

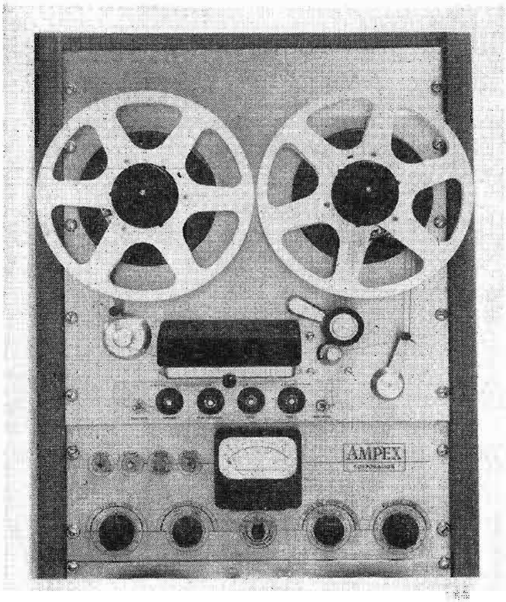

FIG. 4-1. Reel-to-reel tape transport. (*Courtesy of Ampex Corporation.*)

Two of the motors are used for supply and take-up reel control, which serves to keep constant tension on the tape during recording or playback. A third motor, usually of the hysteresis-synchronous type, is used to control the tape speed through the heads. Usually the tape passes between the motor shaft and a rubber pinch roller. To achieve fast starts, the motor should be running before the tape is started so the motor does not start under load. To start, a solenoid-actuated pinch roller moves the tape against the motor shaft, resulting in a very fast starting time and almost immediate stability.

For the fast-forward and rewind functions, power is removed from the pinch roller solenoid, allowing the tape speed to be controlled by the torque motors. Power can be varied between the two motors, by either a rheostat or switched resistors. The tape moves in the direction (and at a rate of speed) determined by the relative power division.

Cartridge Type

Another type of mechanism coming into general use in the broadcast field employs a continuous loop of tape.[1] A typical example is shown in Fig. 4-2. It is usable where a rewinding function is not required. The tape is contained in a special cartridge which allows the tape to be drawn from the center of the loop. This action causes the entire loop to turn and wind the used tape on the outer part of the loop. Since this does not require any provisions for take-up or rewind, the transport mechanism consists simply of the capstan motor and pinch roller.

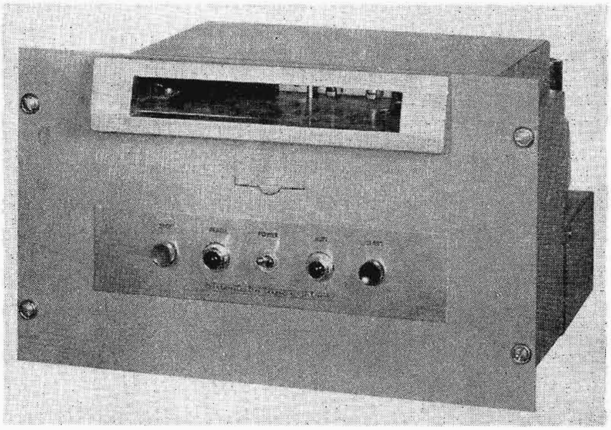

FIG. 4-2. Cartridge type of tape transport. (*Courtesy of Collins Radio Company.*)

One such machine on the market, which is known to have broadcast quality, has cartridges available that will play from 40 sec to 45 min. There are three basic sizes of cartridges containing from 25 to 1,700 ft of special lubricated tape. The tape speed is 7½ ips. The cueing is controlled by a tone burst which is recorded at the beginning of the recorded information. After the recorded information is played through, the machine is allowed to run through the remaining tape until the tone burst is played again. This tone stops the tape travel and leaves the cartridge cued up for the next time it is used.

Multiple-track Tape

A third type of mechanism recently introduced consists of a tape of about 13-in. width on which over 100 tracks can be recorded. This results in a mechanical transport similar to a piano roll player. This machine is shown in Fig. 4-3. The erase, record, and playback heads are manually moved across the width of the tape to select the proper track. The mechanism winds the length of tape from one roll to the other. The tape speed is approximately 5¼ ips, with a 90-sec recording requiring about 45 ft of tape. The particular model now on the market uses small windows (where the oxide is removed from the tape) together with small lamps and photoelectric cells to determine the beginning and end of the tape for automatic rewind

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[1] Extensively used in Europe for musical-type station ID's.

and cueing functions. All tracks are cued up side by side, ready for instant selection. Other methods, such as automatic recording of control tones or silent sensing amplifiers, could also control the functions.

FIG. 4-3. Multiple-track tape transport. (*Courtesy of Gates Radio Company.*)

Magnetic-disc Type

The magnetic-disc recorder (as illustrated in Fig. 4-4) is quite a different machine but functions in a conventional manner. There is presently only one model on the market generally known to be suitable for broadcast use. The transport mechanism is identical with a standard phonograph turntable or changer unit. This uses a pregrooved disc, coated with standard oxide, the same physical size and shape as a 45-rpm disc. However, to get the necessary 70 sec recording time, the turntable revolves

FIG. 4-4. Magnetic-disc mechanism. (*Courtesy of RCA.*)

at 33⅓ rpm. The record-reproduce head is mounted in a conventional pickup arm and is very similar to a conventional tape-recording head.

When the disc is intended for use on an automatic changer, the cueing and changer trip functions are controlled by using a high-frequency control tone, which is recorded immediately before and after the audio signal. The unit described nses a 10-kc tone applied to the recording signal after the 10-kc audio components have been removed. They are generally removed by filtering earlier in the amplifier, by means of a bridged-T notch filter, to prevent false operation by the audio signal.

This same bridged-T circuit is used during playback to prevent the control tone from being fed to the program output connection. A separate amplifier, which is frequency selective, is nsed to amplify only the control tone and operate a plate circuit relay. When the disc is being cued, the changer stops quickly (upon detection of the 10-kc tone) at the beginning of the disc. When the tone is detected again, it operates the changer trip mechanism.

Erase and Record-reproduce Heads

Much of the performance of a magnetic recorder depends on the performance of the heads. Usually the erase head is the least critical, requiring only that it make good contact with the tape and that it pass the symmetrical waveshape of the erase voltage. It is almost always mounted separately from the record and reproduce heads and preceding them in the tape path. Some machines use one head for both recording and reproducing. Although this method is more economical, it does not allow direct "off-the-tape monitoring" while recording. Also, separate heads allow the gap spacing of each head to be optimum for the purpose.

The recording head is not so critical in this respect, but the reproducing head is very critical because the gap width controls the high-frequency response. The azimuth alignment of the heads is also critical. They should be aligned with a standard test tape to allow interchangeability of tapes on machines. Also, it is very important that the heads make good contact with the tape, or a considerable loss of high frequencies will be noticed. Therefore, a regular cleaning schedule should be conducted.

The gap in the reproduce head should be as small as possible so that it will intercept less than one wavelength of the signal on the tape (at the highest frequency to be reproduced). Of course, there is a practical limit to narrowing the gap, for both mechanical and signal-to-noise ratio reasons. The narrower the gap, the smaller the induced-voltage level. Therefore, a practical compromise must be reached.

At present the gap spacing of the heads can be reduced sufficiently that (with proper azimuth adjustment head contact and bias current) it is possible to secure response essentially flat to 15 kc at a tape speed of only 3¾ ips.

Amplifiers

The recording amplifier is used to raise the output of a microphone to the level necessary to drive the recording head. Since head gap width, tape velocity, and many other factors determine the frequency response, noise, and distortion of the record-reproduce process, it is advisable to include as much preemphasis as possible in the recording amplifier. The standard recording curves shown in Fig. 4-5 were derived from the tape-distortion characteristics. The tape, when recorded with these curves, will give approximately the same distortion at all frequencies involved in the playback process.

The recording amplifier usually contains the bias and erase oscillator, which drives the recording and erase heads. It is general practice to provide sufficient amplification in professional machines to record directly from a low-impedance microphone and bridge a balanced 600-ohm line with +8 VU of program level. Figure 4-6 is a block diagram of a professional recording amplifier.

The playback amplifier raises the signal (generated in the playback head) to a level suitable for feeding the console or other speech input equipment. This level

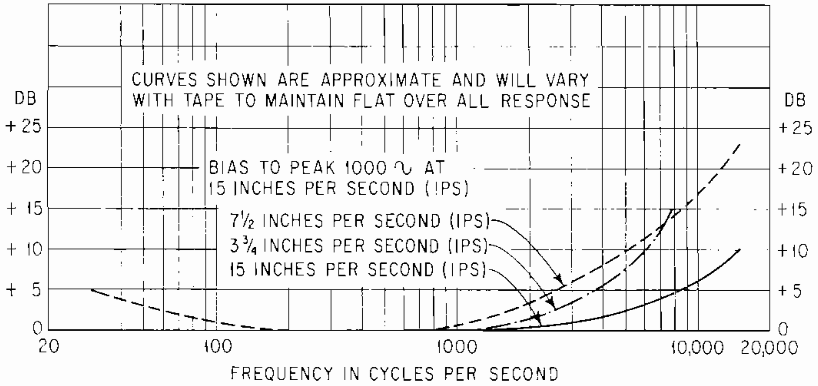

Fig. 4-5. Standard recording curve. (*Courtesy of Ampex Corporation.*)

ranges from −20 dbm to +8 VU. This amplifier also contains a deemphasis circuit to adjust for flat over-all frequency response. Figure 4-7 shows the standard playback curves. They are derived from the nonlinearities of the record-reproduce process as described above. In addition, there is a characteristic rise of approximately 6 db/octave in the playback process (until head losses and gap width overcome it at the high-frequency end) which accounts for the linear section in the playback curve. The total correction required to obtain a flat frequency response from the entire process can be determined by combining the recording and playback curves for the desired speed.

Other requirements in a good playback amplifier include a type of input tube which has an exceptionally low inherent noise level, a good grounding system, and filament bias and balance, or direct current on the filaments. Distortion is seldom a problem in a playback amplifier if normal precautions are taken.

In testing a playback amplifier, it is advisable to adjust the input level to obtain a constant output level for all frequencies. This prevents excessive overloading, which will never occur except on the test bench with a constant input. Figure 4-8 is the block diagram of a typical playback amplifier.

All tape recorder-reproducers have precision components that require periodic maintenance and adjustment. Brake-tension adjustments should be checked with

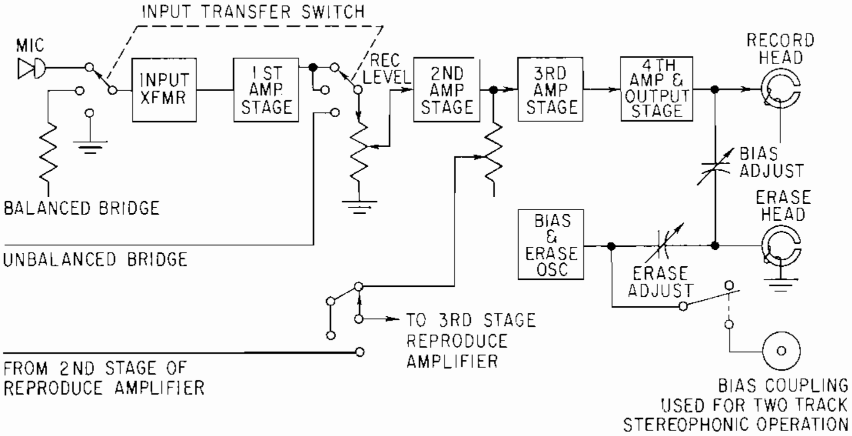

Fig. 4-6. Block diagram of recording amplifier. (*Courtesy of Ampex Corporation.*)

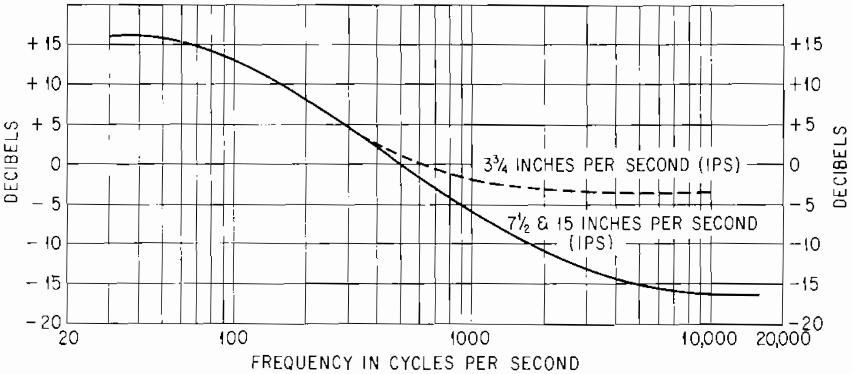

FIG. 4-7. Standard playback curve. (*Courtesy of Ampex Corporation.*)

the methods and equipment prescribed in the instruction manuals to maintain optimum performance. No attempt should be made to improve or change the basic design of a tape machine without approval from the manufacturer.

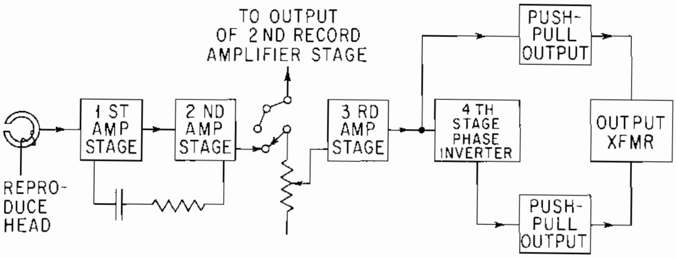

FIG. 4-8. Block diagram of playback amplifier. (*Courtesy of Ampex Corporation.*)

RECORDING-MEDIUM CHARACTERISTICS

Types of Tape

Two general types of recording tape are generally available. These are the acetate base and the polyester, or "mylar," base. The acetate base is a general-purpose tape for most recording purposes. However, the polyester base has many advantages for the broadcaster due to its more rugged nature.

Acetate-base tape uses 0.0015-in.-thick cellulose acetate. The breaking strength of this tape is on the order of 4 to 5½ lb for standard ¼-in. width. Normal recorder-tape tension is but a few ounces, so there is a reasonable safety factor to care for peaks of tension during machine starts and stops and for wide variations in strength caused by changing humidity and temperature. The coating on the base consists of a carefully controlled mixture of magnetic material and a binder of tough flexible combinations of synthetic resins. Since tape may be stored tightly wound on reels for long periods, there must be no tendency for one layer of tape to stick to the next. Also, the tape must remain flexible so it will conform to the heads and not impair high-frequency response. The coefficient of friction between the binder and metal heads or guides must be low so the tape will move smoothly without flutter or squeal. This antifriction quality is part of the formula and should not rub off on the heads or guides to excess, as this will foul the head gap or build up a deposit, resulting in excessive wear. Regular cleaning is a must, to prevent even slight build-up of deposits.

Polyester-, or "mylar-", base tapes have the same characteristics in the oxide but are more stable (in the backing material) to temperature and humidity changes and somewhat stronger and more shock resistant. This tape is virtually free of dimensional changes (and distortion induced by these environmental changes) but does have a disadvantage in that a high shock or excessive abuse causes the tape to stretch permanently, causing a "wow."

This stronger base allows thinner tapes to be made, providing longer continuous programming. By using a base only 0.5 mil thick on a standard 10½ in. NAB reel and operating the machine at 3¾ ips, it is possible to record or play over 4 hr of programming without a single break. This is particularly useful for delayed programming of a sports event or opera. As this tape is very limp, excellent contact is achieved with the heads. This limpness causes the reel to wind unevenly occasionally, and it is helpful to obtain a special reel which has a narrow spacing between the flanges, on the order of 0.28 in. instead of the standard 0.345-in. spacing. It is possible to grind down existing flanges to make these special reels.

Print-through

If a tape is recorded and stored for a period of time, there is a phenomenon that sometime occurs called print-through. It occurs because a strongly magnetized tape is wound next to an unmagnetized portion and some of the magnetic effect transfers from one layer to another. Since the transfer is through a layer of acetate or polyester, the effect is quite small but often objectionable for high-quality broadcast work.

It has been found that the effect becomes serious as the recording level increases. Print-through will decrease about 2 db for a 1-db decrease in recording level. The effect increases with time of storage, higher temperatures, or exposure to stray magnetic fields. Most of the effect is in the mid-frequency range, with high- and low-frequency sounds virtually unnoticeable. Use of the thinner base tapes will slightly increase the effect.

If a tape is to be stored for some time, the following precautions will help in eliminating print-through. Program peaks should be held to a level not exceeding 0 VU on the recording meter. The storage temperature should be kept below 75°, and the reel placed in a steel can to protect against stray magnetic fields. To protect valuable recordings, it would be well to use a special tape (which is available) that has about 8-db lower print-through effect than standard tapes. Occasional playing or rewinding of the tape will redistribute the adjacent layers, thereby reducing the effect. Most machines wind the tape more tightly when rewinding than when playing. Therefore, it would be wise to store tapes before rewinding to take advantage of the slightly increased spacing between adjacent layers.

APPLICATIONS

The most common broadcast application is that of recording network or local programs for delayed broadcast. More recently, stations have started to prerecord commercials for audition to clients and on-the-air accuracy. Other interesting effects can be had by prerecording sound effects on a continuous basis, and (by means of the continuous-loop mechanism) the effect is available for any desired period of time. Reverberation, or "echo," effects are available on any machine which has separate record and playback functions and allows a delay proportional to the head spacing and tape speed of the machine.

A very flexible reverberation machine can be constructed using a continuous loop of tape, a variable-speed motor-drive capstan, and a number of heads. The loop of tape need be only 2 to 5 sec long. An erase head should be first in line followed by a recording head. Thereafter, a number of playback heads can be positioned on slides so they can be moved to various locations along the tape path to secure various degrees of time delay.

Precautions should be taken to be sure the azimuth alignment of the heads is not disturbed when they are moved. The outputs of each head can be connected to a playback amplifier where the required equalization and filters can be added to change the frequency response of each delayed portion of the audio. Outputs of the playback amplifiers are then combined and fed to the program output. If desired, a portion of this signal can be reinserted with the input to the original recording head for additional reverberation.

In operation, the faster the tape speed (and the closer the playback heads are to the recording head), the shorter the reverberation time. Many effects can be obtained by varying the gain controls on each playback amplifier.

Another use of the tape machine is to control automatic station equipment. With the use of a stereo tape recorder, one track is recorded with program announcements and the other track recorded simultaneously with control tones, which are used to perform automatic functions. When the playback is made, frequency-selective relays may cause the program audio to switch from the controlling machine to an automatic record changer or other tape playback machines at the conclusion of an announcement. Another tone will allow the tape machine to cue to the beginning of the next announcement and wait for a manual or automatic "command" to start playback again. Various tones can be used to trigger the start of several record changers or other similar automatic tape playback units.

Some automatic programming machines use subsonic and/or high-frequency control tones on the same track with program material. This may limit the flexibility of the system because not many of the tones can be used on a single track and retain good program quality. The useful frequency response of the tape falls within the audible range, and the tones used are generally at the lower and upper fringes of this band. Frequencies of 20 and 10,000 cycles are common in such systems. Their removal from the program material causes very little deterioration in program quality.

The multiple-track tape machine is ideally suited for short announcements such as station breaks, time announcements, sound effects, etc. It is also suitable for spot announcements and themes of much longer duration. Inserting subsonic or supersonic tones at the end of the announcement will allow automatic rewinding immediately or control of other programming devices.

The continuous-loop transport mechanism can be made to cue itself (for repeating a recorded announcement) automatically. When the recording is started, a tone is recorded momentarily on the second track. The machine is so connected that it will run until a playback head on this control track detects the tone, which immediately stops the machine (automatically cued to the original starting point). If the machine is manually stopped at the conclusion of the first recording, additional announcements can be made on the same loop, provided sufficient tape is on the loop. When in the playback function, the machine will sequentially recue to the start of the next announcement. An additional automatic function can be had by recording a different frequency of tone burst at the beginning of each announcement. By the use of frequency-selective relays, individual announcements can be automatically selected. A disadvantage to this type of unit is the absence of a fast-forward or rewind function. The complete tape length must be run at standard speed if it is desired to audition any particular announcement.

Similar but less flexible automatic control functions can be had with a metal-foil backing material applied to the reverse side of the tape. A pair of contacts ride on the tape and shut off the motor when the circuit is completed through the foil and motor-control relay.

A voice-operated relay can be used to control the cueing of the tapes. In this case, the machines run a predetermined time after the last audio signal. A disadvantage in this system is the wide tolerance in both the timing circuit and the make-up of the recorded tape. A better system uses a playback head a few inches ahead of the regular program playback head. This special head is connected to a voice-operated relay to "anticipate" the audio and stops the machine when cued a predetermined number of inches ahead of the next announcement.

CIRCUIT CONNECTIONS

Most professional tape recorders have microphone and bridging inputs. If used correctly, these cause very little trouble. However, on some machines, the bridging input is unbalanced (one side grounded). This invariably causes problems in the broadcast station. A balanced input can bridge or match either a balanced or unbalanced source (if there is no center-tapped ground on the input) with no difficulty. Thus, it would be best to modify machines that have unbalanced inputs and make them balanced.

Adding a Transformer

An interstage transformer would accomplish the job, it seems. However, it is difficult to find one that has good shielding and frequency response. Also, it is hard to find one that will tolerate the impedance mismatch that generally occurs without frequency discrimination.

A high-quality input transformer is quite easy to obtain. This can be connected as shown in Fig. 4-9. This circuit will give 31-db loss in the bridging pad (when bridging a 600-ohm terminated line), but the transformer will give 20-db voltage gain; thus, the net loss is only 11 db. This loss will seldom be a problem, since most bridging is performed on high-level lines.

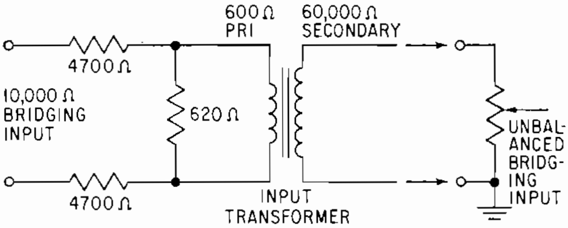

Fig. 4-9. Adding a bridging transformer.

Adding a Bridging Pad

Another method of installing a balanced bridge would be to connect a bridging pad to the microphone-input transformer. The microphone input is balanced on nearly all professional tape machines. For best results, a matching pad should follow the bridging pad. This splits the loss required and prevents frequency discrimination, which may occur in a single pad. Figure 4-10 shows a typical circuit. The 10,000/600-ohm bridging pad has 31-db loss, the 600/150-ohm matching pad has 30-db loss, which gives a total loss of 61 db. When bridging a 600-ohm terminated line with +8 VU level, the microphone input receives −53 dbm. This will give a good signal-to-noise ratio, yet prevent overloading of the input stages.

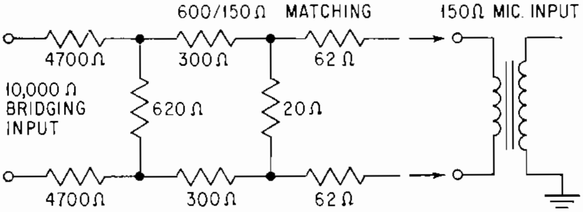

Fig. 4-10. Adding a bridging pad.

Converting High-impedance Recorder-Reproducers

Most professional high-impedance machines have a cathode-follower output which can be loaded with 10,000 to 20,000 ohms. Use a good-quality output transformer, with the 10,000- to 20,000-ohm primary connected to the output of the playback amplifier. The 150- to 600-ohm secondary will match into most speech input consoles.

The high-impedance input of these machines is generally in the 60,000- to 100,000-ohm range. Use a good-quality input transformer, with the 60,000- to 100,000-ohm secondary connected into the high-impedance microphone input of the recording amplifier. Connect the low-impedance microphone into the proper impedance on the primary winding of the input transformer.

RECORDING FROM SINGLE-CHANNEL CONSOLES

If the recording material is being fed through the program amplifier of the console, of course, this is no problem. The recorder may simply bridge it (as is the case, of either program amplifier, in a dual-channel console). Where it is desired to record material different from that being broadcast, it is best to connect the audition bus of the console into the microphone input of the recorder. The bus impedance of most commercial consoles is from 75 to 200 ohms and in the area of −45 to −55 dbm in level. Choose the microphone impedance closest to the bus impedance (as stated in the console instruction manual, or measure the audition bus with an ohmmeter). This method generally works very satisfactorily. If the level is higher than necessary, a series resistance, bridging pad, or bridging transformer can be used to decrease it.

If it is desired to switch the audition bus output into several tape recorders, some consoles have utility keys that can be used for this function. Of course, auxiliary keys can be installed in any convenient location that does not introduce noise into the console or the recorder.

Feeding the Console

Most professional tape-recorder playback amplifiers have an output level from −20 dbm to +8 VU. Generally, they are fed into an input channel on the console which does not contain a preamplifier. A level of −20 dbm is suitable for most consoles, because this is the approximate level out of the microphone preamplifiers. This allows the channel attenuators to set at the same position for both types of inputs.

If the output level is +8 VU, it should be reduced to about −20 dbm level. This will prevent the necessity of using the channel attenuator in the section which is normally tapered to cutoff. The same condition is true for output levels of +4 VU. Since these levels are quite common, a 25-db "H" pad is shown in Fig. 4-11 that can be used to compensate these levels with optimum console input levels. It will give −21-dbm level from a +4 VU source and −17-dbm level from a +8 VU source. If the tape recorder is fed into a cueing amplifier, it is best to test the operation with these pads inserted on a trial basis before actually making a permanent installation. It may be necessary to modify the amount of loss to fit a specific application.

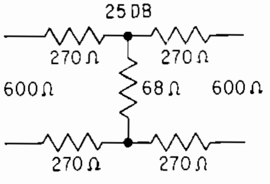

Fig. 4-11. 25-db 600/600-ohm "H" pad.

MAINTENANCE

Lubrication. At the end of 3 months or after 1,000 hr of operation, lubricate the capstan drive motor and capstan idler with a few drops of SAE 20 or manufacturer's recommended lubricant. Most mechanisms require no further lubricant because the bearings are sealed.

Cleaning. The capstan, capstan idler wheel, head faces, and tape guides should be cleaned often (sometimes daily, with heavy use) with ethyl alcohol applied with a soft cloth or other recommended cleaning solution.

Demagnetize All Heads. At least once a month and after every maintenance operation, the heads should be demagnetized. This is required because the accumulated switching transients in daily operation and surges (due to removing tubes, etc.) will gradually magnetize the heads. Magnetized heads will partially erase the tape or disc when they are played and will increase the noise level. This should always be done before using standard test tapes to assure against partial erasure and incorrect readings.

Take-up and Holdback Tensions. These should be checked with a small scale while the machine is running in the normal forward mode. NAB hub size reels should produce 6 to 8 oz of tension; the smaller size should produce 3 to 4 oz.

Brake Tensions. These are adjusted with no power applied to the machine. With the scale pulling the reel in the direction of forward tape travel, the tension should be from 12 to 16 oz; in the opposite direction, it should be from 6 to 9 oz.

Capstan Idler Pressure. The pressure of this idler on the capstan shaft should be sufficient to cause positive drive to the tape, but not so great as to cause the motor to overload and drop out of sync. This is a great deal of latitude. One manufacturer recommends approximately 80 oz of pressure.

Playback Level Adjust. The gain control in the playback channel of the amplifier can be adjusted to give a predetermined level on the output of the playback amplifier from the standard level on the standard alignment tape. This is usually a low frequency to prevent variations resulting from equalization adjustments. Depending on the alignment tape used, the standard level will be full level or 10 dbm below normal level.

Erase Current. See paragraph under Theory of Magnetic Recording.

Bias Current. See paragraph under Theory of Magnetic Recording.

Signal-to-noise Measurements. Properly terminate the output of the playback amplifier, and connect a high impedance noise meter or sensitive VTVM across it. Using the standard playback level from the alignment tape as reference, measure noise below this reference with the tape stopped. If there is a filament balance or other noise balance (except that connected with the bias oscillator), adjust this for the lowest reading.

Replace the alignment tape with new or well-erased tape. Record a section with no signal input. Place a 0.02-μf capacitor across the noise meter input to remove the bias frequency. With a simultaneous record-playback machine, adjust the bias balance control for lowest noise (generally a popping or cracking noise). With a machine with a combination head, record and adjust, playback and observe until optimum results are obtained.

Azimuth Alignment of the Heads. Use a standard alignment tape to align the playback heads for maximum output at the specified alignment frequency to permit interchangeability of tapes and machines. Replace the alignment tape with a new or well-erased tape, and record the highest frequency specified for the speed you are using. On simultaneous record-playback machines, align the recording head for highest output from the playback amplifier. On combination-head machines, record and adjust, playback and observe until optimum results are obtained.

Playback Response. Terminate the output of the playback amplifier, and play back the response portion of the standard alignment tape. Connect the input of the noise meter or sensitive VTVM to the output of the amplifier. The level on the alignment tape is 10 to 20 db below the normal level. Adjust the playback equalizers for the optimum frequency response as specified in the instruction manual.

Record Response. After adjusting the playback response, use a blank tape and audio oscillator to record the frequency range expected. Record the level 10 to 20 db below normal level to prevent any possibility of overloading the tape. With a constant recording input level, adjust the recording equalizing controls to obtain a flat frequency response from the playback amplifier.

Tension Scales. These are somewhat difficult to locate in some areas. They can be purchased from John Chatillon & Sons, 90 Cliff Street, New York City. The following scales are available: 0 to 8, 0 to 16, 0 to 64 (4 lb) and 0 to 80 oz (5 lb) The 0- to 16- and 0- to 80-oz scales are a suggested minimum.

Part 5

VIDEO-TAPE RECORDING

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BASIC PRINCIPLES

The Magnetic Medium

Magnetic recording tape, whether for audio, video, or other recording purposes, contains finely divided ferrous oxide particles deposited on a plastic backing. In the case of magnetic video recording with commercially available rotating-head equipment, the oxide coating must be extraordinarily resistant to abrasion at high temperatures and pressures, must be of a superficial smoothness much greater than that required for direct audio recordings, and must be substantially free from defects which would cause a momentary loss of continuity in magnetic characteristics or of contact with the magnetic heads. For video recording, the plastic backing must be capable of a minute amount of stretching, since stretching of the material is relied upon in the recording and reproducing process to assure equality of recorded track length, in a direction transverse to that of the tape motion, with rotating heads whose effective diameter will change slightly with wear.

The Recording Process

During the recording process, the magnetic medium is moved through the magnetic field which is created at the gap in the recording head, and the resulting flux pattern on the tape is a function of instantaneous magnitude and direction of the original signal *at the moment the tape leaves the head gap.* In so far as the response of the magnetic heads and of the magnetic tape can be made linear, ***flux density on the tape is directly proportional to recording current.***

Reproduction

If the recorded tape is then moved past the gap of a reproduce head, which may be similar to or identical with the recording head, the magnetic flux from the tape will induce a voltage in the windings of the reproducing head. Assuming a constant rate of change of flux density in the moving tape, this voltage is proportional to the number of turns of wire in the head coil, the permeability of the core material, and the efficiency of the magnetic structure at the reproducing frequency. Reproduction is an electrodynamic process, so induced voltage is proportional to the *rate of change* of magnetic flux in the head core. Thus, other effects being ignored, induced voltage will vary directly with relative head-to-tape velocity, directly with reproduced frequency, directly with flux density, and inversely with the wavelength of the recorded signal on the tape.

In typical commercial magnetic reproducing heads, the voltage induced, if the head-to-tape velocity remains constant, will be directly proportional to frequency up to a frequency whose wavelength, as it appears on the tape, *approaches* the effective width of the gap of the head. Above this the head efficiency declines, so voltage will decline, at first gradually, then more precipitously, until it reaches zero at that frequency whose wavelength on the tape equals the effective head-gap dimension.

The Limits of Magnetic Tape Recording

Disregarding the response of the associated amplifiers, the problems of maintaining constant tape velocity and adequate head-to-tape contact and of electrical losses in the head, there are certain inherent properties in the process which define the frequency limits which can be recorded and reproduced and the signal-to-noise ratio which can be obtained.

High-frequency Response

Useful high-frequency response is ultimately limited by the dimension of the head gap or by the resonant frequency of the head or both.

During recording, the tape coating assumes a permanent state of magnetization at the instant it leaves the head gap, so the gap width of the recording head is relatively uncritical. However, in reproducing, the magnetic flux emanating from the moving tape must induce a voltage differential across the reproducing head coil if the current is to flow in that coil. This voltage is induced only as the flux traverses the entire head core, forced into that path by the higher reluctance of the gap. The flux is proportional to the sum of positive and negative fields existing within the head gap at any given instant. Thus, when the recorded frequency is so high that its wavelength is equal to the gap width, the sum of positive and negative flux patterns in the gap at that instant is zero, as is the voltage induced in the head coil. This cancellation effect occurs, also, at multiples of the frequency represented, and for all practical purposes the head is useless above a frequency which is somewhat less than that corresponding to the wavelength of the first gap null.

At any given head-to-tape velocity, the uppermost reproducible frequency can be increased by decreasing the gap width. Limitations are reached when realistic manufacturing tolerances are exceeded or when head output falls to less than usable levels. Induced voltage decreases with head gap, because reduction in gap width constitutes a reduction in the reluctance of the magnetic path across the gap, which is, therefore, approaching a "short circuit" of the magnetic circuit.

The uppermost reproducible frequency can be further increased by increasing the head-to-tape velocity. This increases the wavelength of any given frequency as it appears on the tape.

The resonant frequency of the inductance of the head coil and the capacitance, either actual or distributed, of its circuit either must normally be outside the passband of the system, so that the drop in output after the point of resonance will not adversely affect the frequency response, or must be so placed at the extreme upper limit of frequency response that it provides a small extension of "flat" response. When good engineering design has reduced the circuit capacitance to an irreducible minimum, the only way to increase the resonant frequency is to reduce the inductance of the head coil by reducing the number of turns of wire on the core. This, in turn, reduces the head output over the entire frequency range and will particularly influence the usefulness of low-frequency output.

Low-frequency Response

The lowest frequency which can be reproduced in any tape system is ultimately determined by the lowest signal level which can be tolerated by the requirements of the system at low frequencies. As shown, the voltage developed across the coils of the reproducing head decreases with frequency until a level is reached which is insufficiently above the basic noise level of the system as a whole to be considered useful. Thus, the noise level in the associated electronic assemblies often will determine the low-frequency limit of the tape system. In general, the maximum bandwidth which can be effectively reproduced by any magnetic tape device is approximately 10 octaves.

Signal-to-noise Ratio

The requirements of the system for over-all signal-to-noise ratio usually determine the useful frequency limits of the system. As the signal-to-noise ratio requirement increases, the level requirement at each of the bandpass extremes increases. Thus, as the signal-to-noise ratio requirement increases, the bandpass decreases. The center of the bandpass will depend upon gap width and head-to-tape velocity.

RECORDING THE TELEVISION SIGNAL

The Problem Defined

The television signal contains energy in a bandpass from direct current to more than 4 Mc. To reproduce the 4-Mc signal, we can either decrease head gap or increase head-to-tape relative velocity. If an effective head gap of 0.25 mil (0.00025 in.) is assumed, the required head-to-tape relative velocity must be in excess of 2,000 ips, or more than 110 mph.

Reduction of the gap to an impractically narrow 0.025 mil (0.000025 in.) would reduce the necessary head-to-tape relative velocity to 200 ips. But if this velocity were to be obtained by simply moving the tape at that velocity past a stationary head, it would result either in a playing time too short for practical programming or in reels of cartwheel size. A reel of approximately 38 in. diameter, containing 60,000 ft of tape, would be required to provide a playing time of 1 hr at such a tape velocity.

Recovery of very low frequencies from high-velocity tape would also be impractical if dependence were placed upon direct recovery of long recorded wavelengths. Three seemingly conflicting requirements, therefore, face the designer of a television magnetic-tape system:

1. High relative head-to-tape velocity is needed to record and reproduce the high-frequency components of the video signal.
2. A means is needed to record and reproduce the lowest frequencies in the video signal.
3. Adequate playing time, using reels of reasonable size, is a requirement.

The Commercial "Video-tape" Recorder-Reproducer

Since 1956, magnetic video recorders have been in commercial service. These devices employ four video heads, mounted in quadrature on the periphery of a 2-in.-diameter drum, which rotates at 14,400 rpm. The heads trace a transverse path across slowly moving (15 ips) tape 2 in. in width. The tape is cupped around the head drum by a concave tape guide. The relative head-to-tape velocity is approximately 1,500 ips.

Each head describes an arc of approximately 120° while it is moving across the tape, so that before any one head loses contact with the tape, the succeeding head has made contact. During recording, all heads are fed in parallel. During reproduction, one head at a time is connected to the system through individual playback

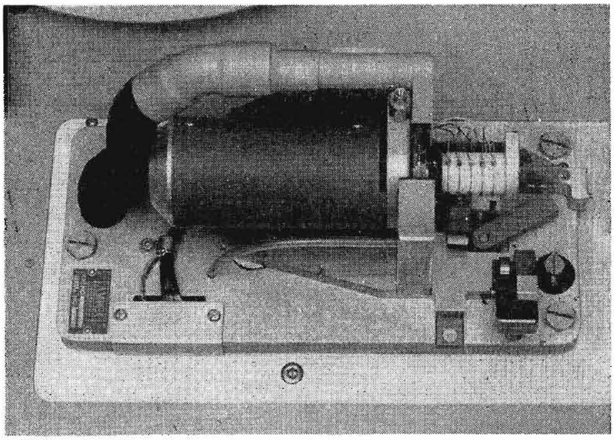

Fig. 5-1*a*. Video-head subassembly. The control track head is visible at the right of the vacuum guide.

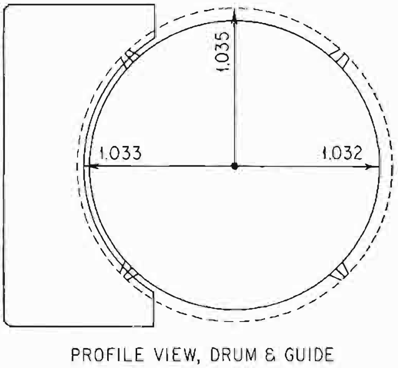

Fig. 5-1*b*. Profile view—drum and guide.

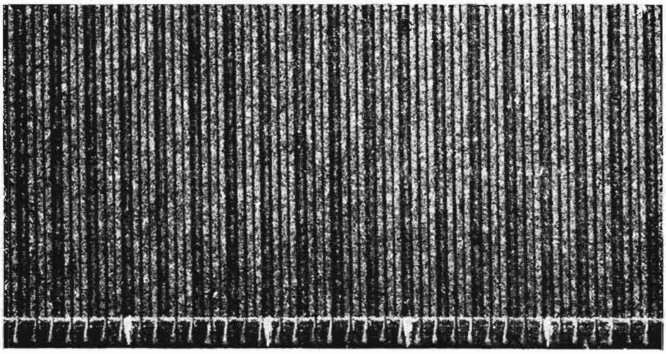

Fig. 5-1*c*. Lower section of recorded video tape after treatment with magnetic particles to render recording visible. Video tracks are 10 mils wide, 15⅔ mils center to center. The control track is at the bottom. Bright traces on the control track are editing pulses, occurring once each field, ¼ in. apart.

amplifiers, switching being accomplished during horizontal blanking intervals by automatic electronic means.

Since linear tape motion is at a velocity of 15 ips, head rotational rate is 14,400 rpm, or 240 rps, and since four tracks are traced transverse to the direction of linear tape motion during each revolution of the head drum, 960 tracks are laid down during each second of recording or reproduction along 15 in. of tape. The tracks are 10 mils (0.010 in.) in width, with a center-to-center spacing of 15⅔ mils. Each frame occupies ½ in. of tape; one field occupies ¼ in. More than 17 horizontal television lines are recorded on each transverse track. A certain amount of information is duplicated at the end of one track and the beginning of the next, since each head traverses approximately 120° of arc across the tape. During the overlapping period, the automatic switcher selects a horizontal blanking interval in which to accomplish the switching from one head to the next. Thus, either 16 or 17 horizontal television lines of video information are reproduced from each transverse track. The thickness of the tape specified for video recording (1-mil base, plus approximately 5-mil coating) is such that 4,800 ft can be wound on a reel 12⅝ in. in diameter, sufficient for 64 min recording or reproduction.

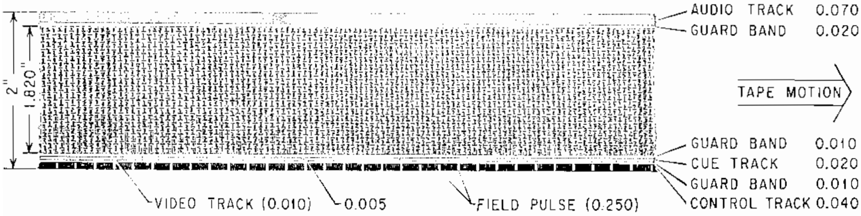

Fig. 5-1*d*. Currently used track dimensions for recorded TV tape.

A Modulation System

Although the uppermost useful reproduced frequency in the system is of the order of 6 Mc, the lowest frequency which can be recovered with adequate signal level is now in the neighborhood of 3,000 cycles. Furthermore, practical apparatus for the purpose of causing the rotating heads to track precisely along the recorded tracks requires some tolerance for off-track reproduction. If the video signal were recorded directly or recorded by amplitude modulation, the video-signal level will vary approximately 10 per cent in the case of a tracking error of as little as 1 mil (0.001 in.). Noticeable and objectionable variations in contrast would result. Thus frequency modulation of a carrier within the passband of the recording system is employed. Since the amplitude of the recovered signal in an FM transmission does not depend primarily upon the amplitude of the RF signal, but instead upon dynamic frequency relations, the recording and reproduction of a frequency-modulated RF signal relieve considerably the necessity for extreme mechanical precision in the playback tracking of the recorded tape. This provides a "margin for error" in operation, maintenance, and manufacture. It is also comparatively easy to recover low-frequency information from an FM signal, so this problem is simultaneously solved.

The FM system is of unusual characteristics, since, with the configuration selected, all the useful information must be contained in the band below 6 Mc.

It has been classically assumed that the highest modulating frequency used in an FM transmission system will not exceed one-tenth of the carrier frequency and that deviation will be large compared with maximum modulating frequency. In the magnetic video recording system, a carrier frequency of 4.75 to 5.85 Mc is employed. Deviation is approximately ±500 kc. The highest useful modulating frequency is slightly over 4 Mc. The modulation index is, thus, approximately 0.125. For this reason, if for no other, the signal-to-noise ratio is somewhat lower than that which is usually associated with FM systems, although experimentation has established that, quite aside from the undesirable contrast shifts which occur in an AM system, the signal-to-noise ratio of the FM system is equal or better. Typical obtainable ratios of peak-to-peak video to rms noise are in the range from 34 to 38 db.

It will be seen that in an FM signal which is deviated ±500 kc from a center in the neighborhood of 5 Mc by modulation frequencies in the neighborhood of 4 Mc, through a system whose bandpass is sharply limited to approximately 6 mc, only the lower sidebands will be fully recoverable. The video magnetic recorder, therefore, operates as a "single-sideband FM" system.

The "sampling rate" of a carrier of this frequency, in conjunction with a modulating frequency of 4 Mc, is, of course, low. The highest frequencies are, therefore, distorted. The effects of high distortion in the high-frequency video bandpass are complex. However, the only detectable effect upon the picture is a small degree of aperiodic waviness in narrow vertical picture elements, which, as far as the eye is concerned, is integrated out by the frame rate. It is visible only in photographs of a single frame.

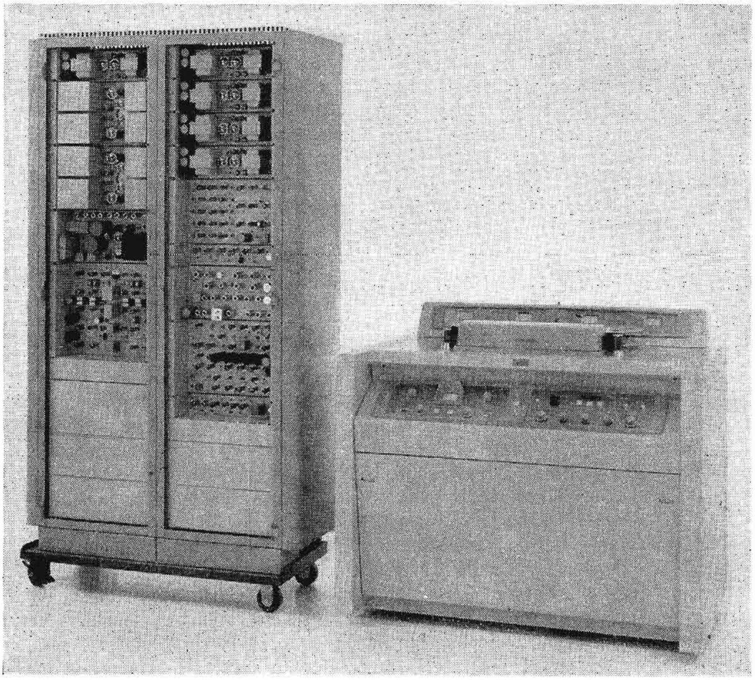

FIG. 5-2. Video-tape recorder complete.

THE "VIDEO-TAPE" RECORDER

General

The "video-tape" recorder may, for the sake of convenience, be divided into the video record-reproduce system, the control system, and the audio record-reproduce system.

The video record-reproduce system consists of all the elements of the recorder which receive, amplify, modulate, record, reproduce, switch, demodulate, and process the composite video signal. The control system consists of the elements of the recorder which transport the tape and control its relation to the rotating heads, the elements which control the mode of operation (record audio and video, record audio only, reproduce, stop, fast-forward, and rewind) and the automatic switchings which accompany these selections.

Modulation

The incoming composite video signal is amplified through four video amplifier stages. Each of these four stages is overcompensated, giving 12 db more gain at 4 than at 0.5 Mc. This is compensation for an opposite characteristic inherent in the modulation process and the demodulator circuit. A video gain control is inserted at the output of the second video amplifier stage. The amplified signal is fed through a cathode follower and then, in the monochrome video recorder, to the grids of a multivibrator. The screen grids of these pentodes are *not* bypassed; the screen voltage, therefore, varies in unison with that of the plate.

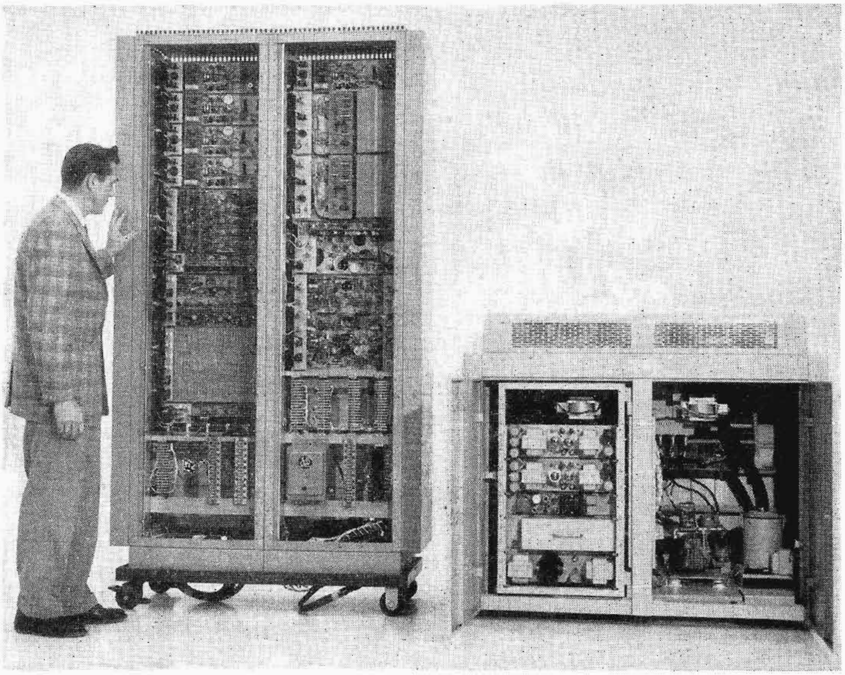

FIG. 5-3. Rear view of complete video-tape recorder.

The composite video which appears at the grids of the multivibrator is clamped at blanking level during the "back-porch" interval by clamping pulses. Direct coupling between the cathode follower and the multivibrator grids prevents the loss of the d-c component during the modulation process. The characteristics of the multivibrator are such that its natural frequency increases as grid voltage increases, so that the synchronizing pulses cause this frequency to *decrease* while signals in the white direction cause the frequency to *increase*. If the multivibrator is adjusted so that its unmodulated frequency is 5.25 Mc, a 15-volt peak-to-peak video signal at the grids of the multivibrator will cause the frequency to vary from 4.75 (sync tips) to 6.25 Mc (white base line). Since the input level control is in the modulating circuit only, it will not affect amplitude of the keying pulses.

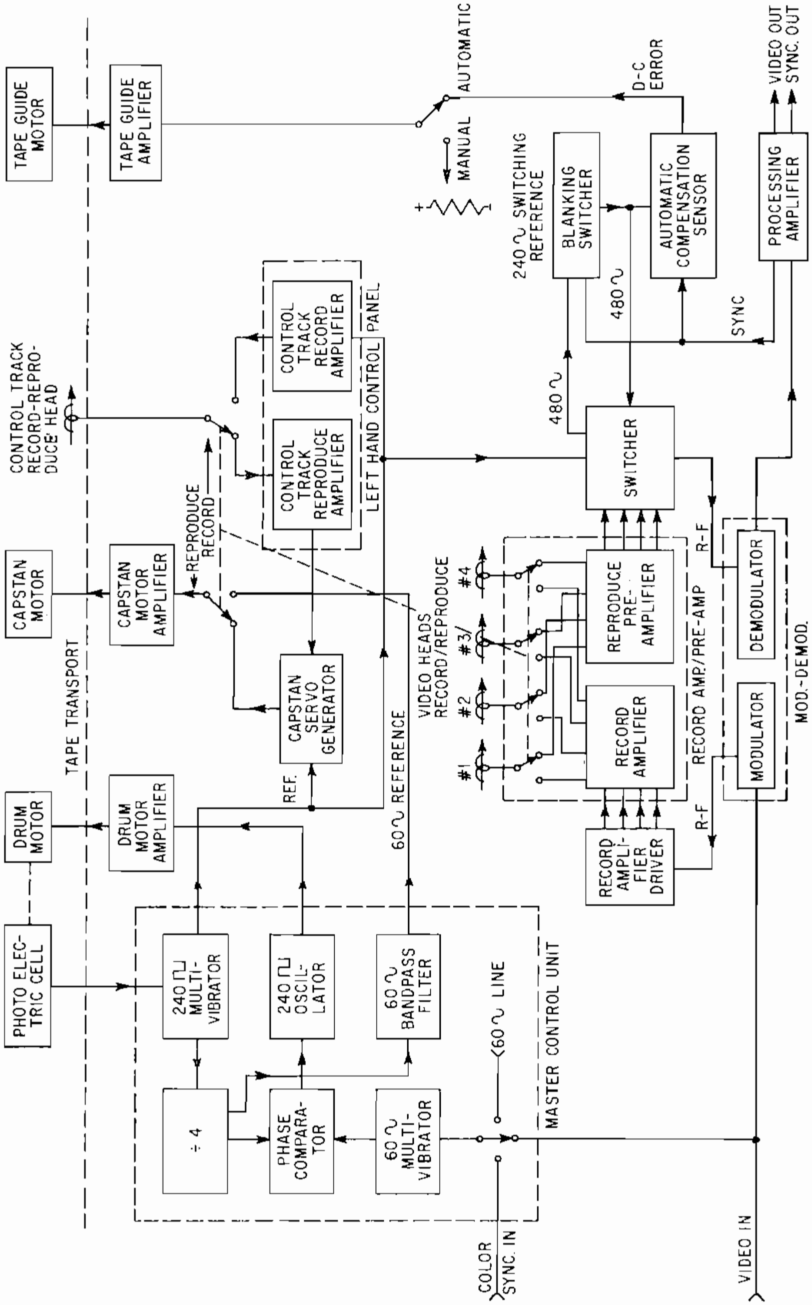

Fig. 5-4. Video-system block diagram.

The multivibrator output is fed through a transformer, providing balanced coupling, so that any simultaneous excursion of the multivibrator plates in the same direction, which might occur in the video signal fed through the tubes, will be canceled. Thus the base line of the FM signal will remain constant, and undesired phase modulation is prevented.

The final stage in the modulator strip is an amplifier whose output is connected to the record-amplifier driver.

The demodulator strip is mounted on the same chassis as the modulator.

Record-amplifier Driver

This chassis provides preliminary amplification of the FM signal from the modulator and supplies a low-impedance output to each of the four record power amplifiers.

This chassis is mounted in the console. Its adjustment points are accessible from the front of the console. The incoming FM signal feeds through a master record gain control and thence to an amplifier chain. The signal then passes through a cathode follower, which feeds in parallel four more cathode followers, providing four low-impedance-source signals, one for each high-power record amplifier. The gain of each of the four individual parallel legs is adjustable, so that variations in record-head sensitivity can be compensated. High-level FM is fed from each of these four sources to the record-amplifier chassis.

Record Amplifier, Etc.

One housing in the console contains four modulator plug-in units, each of which is a record amplifier and reproduce preamplifier, and a fifth plug-in chassis, a photoelectric-cell amplifier, which is associated with the control system.

High-level FM from each of the record-amplifier drivers is fed to one of the record power amplifiers in the record-amplifier–reproduce-preamplifier chassis. The high-power output of each tube is fed, individually through a slip-ring connector on the rotary head mechanism, to one individual recording head. Thus, while each rotating head is constantly fed a signal originating from a common source, the level of record current at each head may be different, depending upon the differing requirements for drive of each individual head. The objective attained here is that of obtaining successive tracks, each recorded at the same flux-density level.

During replay, the individual output of each head is first fed through an individual preamplifier strip. These preamplifiers consist of a pair of cascaded cascode-connected tubes followed by amplifiers. The output at each of the four preamplifiers is fed separately to the switcher chassis.

Switcher

The switcher unit sequentially switches the outputs of the four video heads during the reproduce mode so as to reconstruct a continuous signal from the discontinuously recorded tracks. When used with the retrace switcher, the unit provides automatic timing so that switching occurs only during horizontal retrace periods and does not appear in the reproduced picture.

Each of the four signals is amplified in the switcher chassis through two stages. These are conventional RF amplifier circuits, using shunt peaking in the plate circuits and small interstage time constants to limit the bandwidth to that of the FM signal. The amplified outputs are delivered, then, to the control grids of the gating tubes.

The multigrid gating tubes are so biased that the FM signal will appear at the output only if "trigger" voltages are supplied *both* to the screen and to the suppressor grids. These voltages occur in "get-ready," "go" sequence. The get-ready signal biases one of the two grids to the condition necessary for conduction, while the go voltage biases the last of the grids necessary for conduction, completing the sufficient condition for conduction through the gating tube.

The get-ready signal is derived from the output of a photoelectric cell, which is located at the rotating-head structure. This cell views a disc which rotates with the head drum. The disc is half white and half black. The output of the photoelectric cell, thus, is an approximately square wave of 240-cps frequency. Its instantaneous phase at any moment is thus directly related to the position of the rotating-head drum. Four signals are derived from this 240-cps frequency, one of which is in phase, one lagging by 90°, one the inverse of the 90° lagging phase (thus, a 270° phase), and the last is the inverted 240-cps signal, constituting the 180° phase. The in-phase signal is fed to one of the two gating grids in one of the four gating tubes as the get-ready signal, the 90° phase component is fed to another of the four gating tubes, the 180° phase to another, and the 270° phase to the fourth. Thus, each of the four gates, in turn, receives a get-ready signal slightly before it is to begin conduction of RF and slightly before conduction of RF is to stop in the preceding gate.

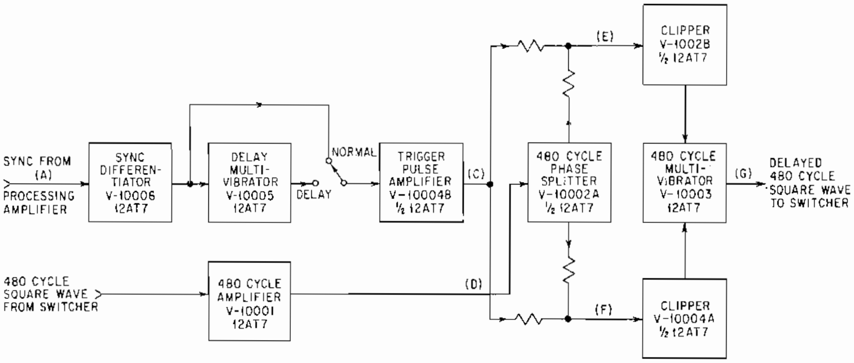

Fig. 5-5. Blanking switcher.

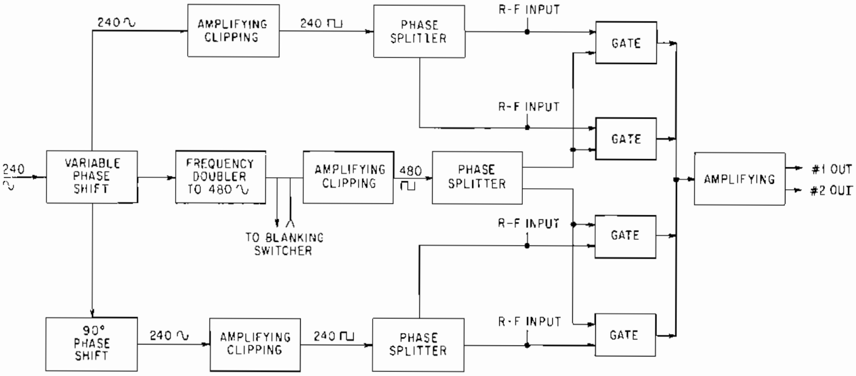

Fig. 5-6. Switcher.

The actual moment of switching is determined by a second grid in each gate, and this is touched off in less than 0.1 μsec by a square pulse derived from the television signal itself through the retrace switcher. This constitutes the go signal. This pulse halts conduction through one gate and begins conduction through the next during the sixteenth or seventeenth horizontal retrace signal on each lateral recorded track on the tape. The parallel output of the four gating tubes is the reconstituted continuous FM signal. This is now amplified and fed in parallel to each of two amplifiers, one of which then feeds the demodulator at low impedance and the other feeds the built-in monitor oscilloscope.

Demodulator

The demodulator strip is located on the same chassis as the modulator. FM, received from the switcher, passes through five dual stages of limiting. As much as 50 db of limiting is employed. The objective is to remove all amplitude modulation and AM noise which may have been introduced during the record and reproduce processes. The signal is again amplified and fed through a cathode follower to the demodulator circuit.

A delay-line demodulator is used. FM is fed in parallel to the grids of the two sections of a dual triode, but one of the two parallel legs is fed through a delay line whose time constant is equivalent to a 90° phase shift at the carrier frequency. The output of the delayed leg is mixed with the nondelayed RF at the plates of the mixing dual triode. One of the two mixed signals, thus, differs from the other in phase in proportion to the deviation from the carrier frequency. Thus, plate signal amplitude increases for frequencies below carrier frequency and decreases for frequencies above carrier frequency. An amplitude-modulated signal is therefore produced, although an FM component is still present. This signal is transferred through a cathode follower and then through a transformer for full-wave detection in a pair of diodes. Cancellation of RF is accomplished as fully as possible through a detector balance potentiometer.

The signal now passes through a three-stage amplifier. Selective inverse feedback is applied to these stages, to modify the frequency response. The signal next passes through a precise 4.5-Mc low-pass filter whose purpose is the elimination of the double frequencies developed in the full-wave rectifier diodes and most of the remaining RF in the region of the carrier frequency. A cathode-anode follower delivers a signal to the output of the chassis, from which it is cabled to the input of the processing amplifier.

Processing Amplifier

Distortion of the higher frequencies, due to the low sampling rate of the 5-Mc carrier, has deteriorated the synchronizing information in the composite video signal. Transients have been introduced during the retrace signal by the switcher. A certain amount of noise originates in brushes, tape dropouts, cross talk, unfiltered RF, and other sources. In the processing amplifier, the synchronizing information is stripped away and new synchronizing pulses are generated and recombined with the video information. Details of the amplifier were presented in an SMPTE paper in April, 1957, published in September, 1958.

The processing amplifier provides two video outputs, one of which is intended to constitute the main video output, the other to feed a picture monitor. A sync output is provided for convenience in locking an external sync generator to tape, and an additional sync output for the retrace switcher and for the automatic compensation senser. Adjustment of video level, blanking level, and sync level can be accomplished locally at the processing amplifier or, through suitable connections to the processing amplifier, at a remote location.

Control Systems

Three different systems comprise the control systems in the video-tape recorder.

1. The solenoid-operated push-button controls over the tape transport
2. The servo tracking system, which assures that the rotating heads, in playback, trace precisely the previously recorded transverse tracks

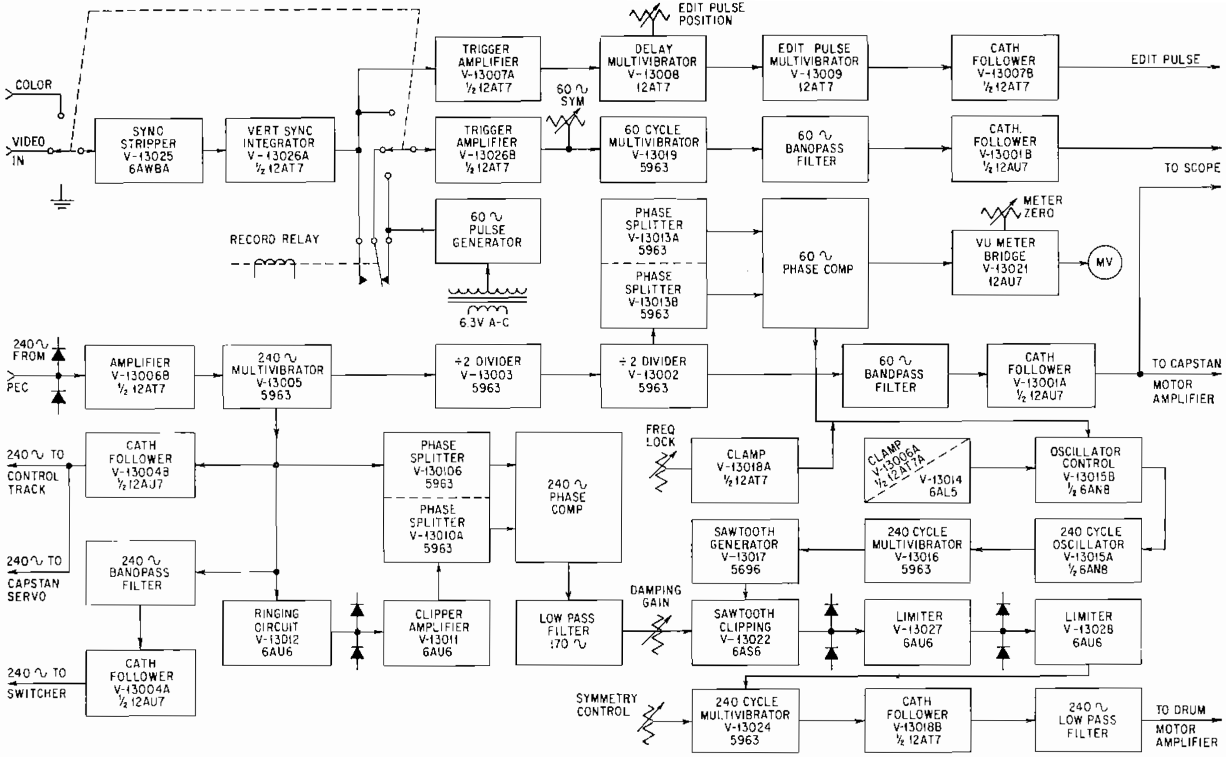

FIG. 5-7. Master control unit.

3. The tape guide servo, which controls the relation between the vacuum tape guide and the rotating head drum, automatically compensating for time-base displacements in the reproduced picture

Tape Transport Controls

Tape motion in the record and reproduce processes is controlled solely by the capstan, which pulls the tape from the supply reel, on the left, through the rotating video head assembly, past the control-track head, the audio-erase head, and the audio record-playback head and drives the tape toward the take-up reel on the right. Each reel hub is mounted on a torque motor. The supply torque motor opposes the motion imparted to the tape by the capstan, thus providing hold-back tension. The take-up motor supplies just sufficient torque to take up the tape as it is supplied by the capstan.

In fast-forward or rewind modes, the capstan idler is removed. The torque of the appropriate turntable motor is reduced by relay-connected resistors under the control of the corresponding push buttons, and tape is pulled from that turntable by the greater torque of the other turntable motor.

Tape Tracking Servo System

Tape speed during the reproducing mode must be controlled precisely to maintain accurate tracking of the video heads as they scan the recorded transverse tracks. The control process starts during the recording operation. During the record process, the rotation of the head drum motor can be locked to any of three 60-cycle reference sources—the vertical sync pulses of the incoming video signal, an external source such as color sync, or the 60-cycle line. Selection of the reference source is made by adjusting a switch at the master control unit.

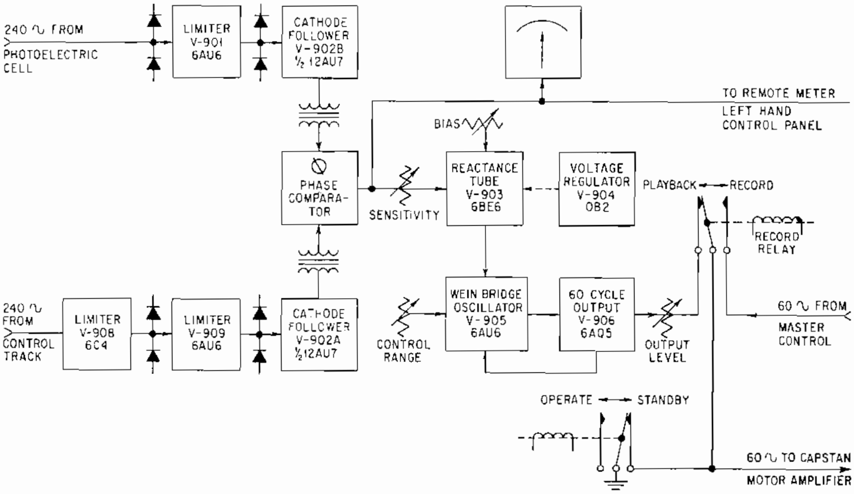

FIG. 5-8. Capstan servo generator.

If the 60-cycle source is to be derived from a composite signal, the vertical rate is stripped from the video information and supplied as pulses to a multivibrator. Sixty-cycle line, if selected, is also applied at this point. Thus triggered, the multivibrator supplies a 240-cycle wave to the phase comparator in the master control unit. The output of the phase comparator is a correction signal, which affects the frequency of a 240-cycle oscillator. The comparator measures the difference between the line-derived wave and a rotary-head-derived wave which is related in phase directly to the rotational position of the head drum. The output of the 240-cycle oscillator drives a power amplifier whose output, in three phases, provides the power to drive the head-drum motor. A disc on the head-drum shaft, painted half black and half white, is scanned by a photoelectric cell. Its output triggers a 240-cycle multivibrator; this 240-cycle signal then constitutes the second signal for the comparator. A servo loop is thus created whose function is to stabilize firmly the relation between head-drum rotation and vertical sync rate.

The 240-cycle signal, which has been derived from the head-drum photoelectric cell, is also amplified and recorded on a longitudinal track at the bottom of the 2-in. tape. The control-track record-reproduce head is located on the video head subassembly, very close to the rotating video heads. The signal recorded is a precise record of the continuous series of positions occupied by the head drum during the recording, and thus is the magnetic counterpart of film sprocket holes.

The 240-cycle drum-derived signal, after division to 60 cycles, feeds a power amplifier, during recording, which provides the power to drive the capstan motor. Thus, an electronic "gear chain" intimately connects the motion of the head drum to that of the capstan, so that tape motion is directly controlled by the rotating video head drum.

In the reproducing mode, the same choice of 60-cycle input can be made. Again, the head-drum motor operates within the servo loop described above. But the capstan is not, in reproduction, under the same direct control by the head-drum motor. Instead, the capstan motor amplifier is driven by an oscillator whose frequency is influenced by a phase comparator in the capstan servo generator. This phase comparator measures the difference between the 240-cycle head-drum-derived signal, at the time of reproduction, and the output of the control-track reproduce amplifier, thus modifying the instantaneous rotary position of the capstan, at any given time, in such a way that the *same relations* exist between *instantaneous head-drum position* and *tape motion* as existed at the time of the recording. In this way, the rotating video heads will precisely trace the recorded tracks. It is possible, during reproduction, for the rotating heads to be off track somewhat, although each tracing will be off track by the same degree. A manual control is, therefore, provided so that the automatic tracking can be brought precisely in line with the recorded tracks. Once so adjusted, precise tracking will be maintained for the duration of the replay.

In the video-tape recorder, the master control unit contains the vertical sync stripper, input multivibrator, phase comparator, 240-cycle oscillator, 240-cycle multivibrator, $^{240}/_{60}$ divider, and a 60-cycle bandpass filter whose function is to supply clean sine-wave signals to the capstan motor amplifier.

The capstan servo generator is a separate unit, which contains the phase comparator, used during reproduction to derive a correction signal from the 240-cps drum rate and the 240-cps control track and the comparator-influenced oscillator which supplies drive to the capstan motor amplifier in the reproduce mode.

Control-track record-reproduce amplifiers are contained in the left-hand control panel on the recorder console.

Tape-guide Servo Control

The video head drum contacts the tape inside a concentric groove in the vacuum guide on the video head assembly. Vacuum is applied to the back of the tape through the vacuum guide at a constant level. The relation of the guide groove to the rotating head drum is, during recording and reproducing, so intimate that the tape is minutely stretched in a direction lateral to its motion during the passage through the groove in the guide. The degree of stretch is determined not by the vacuum applied, which is constant, but by the space between guide and drum, which is variable. The length of the track being recorded or reproduced, and hence the precise time occupied by the tracing of a track, is thus minutely variable. When the reading rate is precisely equal to the rate at which the track was written, the reproduced picture will be free of horizontal time-base aberrations. When the reproducing rate is different from the recording rate, vertical picture elements in each of the 16 bands in the picture will be diagonally offset, creating the "venetian blind" effect. Control, therefore, must be exercised over the precise position of the vacuum guide with respect to the head drum.

The position of the vacuum guide is determined by a small motor which is geared to the guide. Manual control for this motor is provided for test and maintenance procedures. In normal operation, control is exercised by the automatic compensation senser, whose output is amplified through the tape-guide amplifier, in the console, to control the tape-guide motor.

The automatic compensation senser provides an error signal when the tape guide is not correctly positioned. This error signal is fed to the tape-guide amplifier, which repositions the tape guide so as to remove the error signal. The error signal is derived from the reproduced video signal by sensing a time-displacement error caused by incorrect positioning of the tape guide. Sync pulses from the output of the processing amplifier are differentiated and clipped so as to produce positive pulses which correspond to the leading edge of the horizontal sync pulses. These positive pulses are fed as trigger pulses to a monostable multivibrator adjusted to provide a normal positive pulse of approximately 57.5 μsec. Since the horizontal sync pulses are spaced at 63.5-μsec intervals, approximately 6 μsec will elapse between the time that the multivibrator reverts to its stable condition and the occurrence of the next triggering pulse. As a consequence, a negative 6-μsec pulse is produced. Applied across an *RC* network, these become a series of sawtooth pulses, occurring at a rate corresponding to the horizontal sync pulses, whose peak amplitude is constant *as long as the time interval between the sync pulses is constant.*

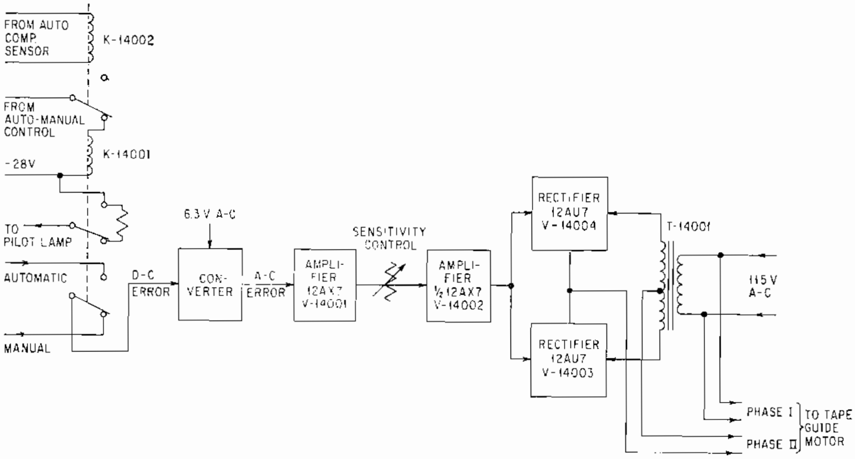

FIG. 5-9. Tape-guide amplifier.

But if the tape guide is not positioned correctly, a timing error is produced each time the heads are switched (every 16 horizontal lines). This would result in a corresponding change in the charge time of the *RC* network, resulting in an amplitude variation in the tip of the sawtooth wave.

The voltage at which the sawtooth wave is sampled can be selected so as to correspond, through the tape-guide amplifier and tape-guide motor connected, to correct tape-guide position. Once this value is set, negative or positive excursions from this selected voltage, since they represent time-base shifts, indicate negative or positive excursions from correct tape-guide position, and suitable correction signals may be generated and fed to the tape-guide servo motor. The sampling circuit uses as a reference the 480-cycle square wave which establishes the head switching time. This is drawn from the switcher unit.

Correct adjustment of the unit can best be made by playing a laboratory-standard recorded video tape on the machine, manually adjusting the head guide, zeroing in the automatic control to the then-existing manual control, and switching to "automatic" operation, after which the machine will both record and play back according to the standardized track length.

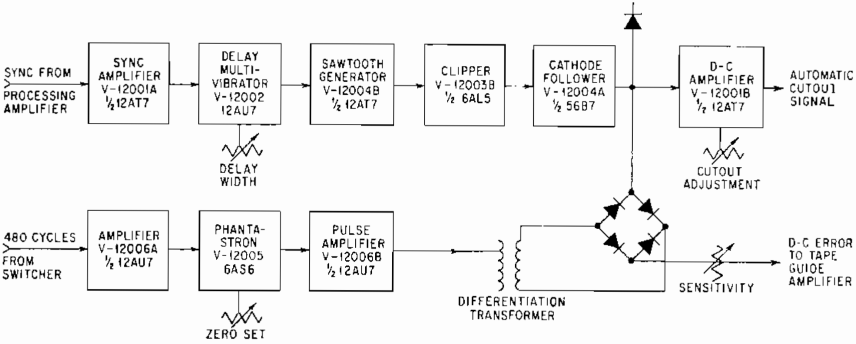

Fig. 5-10. Automatic compensation senser.

CUEING VIDEO TAPE

Since the video-tape recorder records the entire composite video signal, it follows that the output of the recorder is complete with sync. All switching operations which involve the output of the recorder, in playback, therefore must be planned with this in mind.

It is, of course, entirely feasible to lock a nearby synchronizing generator to the output of the video-tape recorder so that switching from tape to live or tape to film can be accomplished without any interruption or change in the synchronizing information. Switching *to* video tape, however, always involves switching the synchronizing source from that which preceded the change to the video-tape output.

Thus, the playback of the tape machine can be faded, wiped, or dissolved into the following picture if sync source for the following picture is local and has been locked to the playback of the tape recorder. The tape output can be split-screened with another picture if the sync information for the other-than-tape half of the split-screen image is locked to sync from tape. Such switchings cannot be accomplished, however, if the source of sync for the upcoming picture is remote or otherwise incapable of being locked to the sync from the tape.

It follows, then, that it will not always be possible to dissolve or wipe from any source sequentially *to* the tape playback. A local insert can be wiped or dissolved into a tape playback if sync for the insert is derived from a sync generator locked to the sync output of the running tape machine.

A "roll" *may* occur when switching from network, local-live, or local-film to tape for the same reason that a roll may occur when switching from network to local without locking the local generator to the incoming network sync.

The video playback does not begin instantly after the "play" button is depressed, but the interval between depression of the "play" button and the upcoming of stable picture is stable and predictable. About 5 sec is the period to which the machines are usually adjusted.

In order to provide precise cueing of switches from other sources to tape, audio methods are sometimes employed. With or without the recording of video, audible "beeps" at timed intervals may be recorded on the sound track down to the beginning of program. Usually, these beeps are automatically generated and consist of ⅕-sec tones spaced 1 sec apart. At the moment of the beginning of the recorded program, audio is switched from the beep generator to the program source. Thus, it is possible manually to find the beginning of the program audio track by listening on the sound monitor of the recorder, then to back the tape manually through the desired number of recorded beeps to a point 5, 10, 15, or any other desired number of seconds before the beginning of program. Because the tape motion begins approximately $\frac{1}{10}$ sec after the depression of the PLAY button, all beeps will be heard and a prearranged "count-down" signal is given to video control, indicating that the recorder is in operation and that the picture will be upcoming in the agreed-upon time.

Variations upon these methods are employed at various video-tape recording installations. In some cases, monoscope pattern, along with timed audio beeps, is recorded for exactly 1 min prior to beginning of any program. This gives visnal indication, upon replay, that the playback is of good quality and gives continuous audible indication of the time remaining before picture comes up from the tape playback. In still other cases, picture is recorded throughout the 1-min interval, changing every 5 sec, so as to give a visual as well as an audible "count-down."

Methods of cueing video tape are under consideration by the SMPTE VT Standards Committee in which NAB participates.

INTERCHANGEABILITY

When a tape playback is displayed on a picture tube, the picture is made up of 16 bands of 16 or 17 television lines each. Every band represents the output of one only of the four rotating heads. If each band is exactly like the others, then the bands are undetectable. A picture of, say, 35-db signal-to-noise ratio, with all bands having that value, is entirely acceptable. But if there is a *difference,* as there may be when head outputs are not equal, then banding becomes visible even if the worst band is *better* than, perhaps, 35 db. The human eye is a very efficient comparator, even though it's not efficient as an absolute-level measuring device.

It is possible to adjust the gain of the four individual preamplifiers so that the output from all bands is equal on any given tape. But that doesn't solve the problem entirely. The control system of the recorder is arranged so that when a recorder is playing back one of its own tapes, each head reads out exactly the same tracks it recorded. Therefore the spacing of the 10-mil tracks on the tape can be fairly erratic. Likewise, the azimuth alignment of the head gaps may be a trifle off perfect perpendicularity, and it won't matter as long as the tracks are always reproduced by the head which recorded them. But if tapes are interchanged, very little looseness can be tolerated in the spacing of the tracks, or noise banding will appear owing to low output from those heads which are slightly off track. Any substantial deviation from a common azimuth alignment will be disastrous, since the highest frequencies will be the first to be lost, and the carrier frequency of the FM system is near the upper bandpass limit of the recorder.

The solution to these banding problems lays in establishing extremely tight tolerances on drum wobble and on head azimuth alignment. Fortunately, the picture itself gives a greatly magnified representation of any fault which may exist in the head structure, so the tolerances can be adjusted out, in production, without the invention of some new kind of supermicrometer.

Small differences in frequency response among the heads were not very important in monochrome-television recording. But with color, where minute variations in frequency response become large variations in color-carrier phase, individual equalizers are required for each individual head. This is not beyond possibility in commercial production. Head structures are not sufficiently refined that individual differences are small, and adjustable equalizers in the separate head amplifiers are adequate to the task.

Time-base Banding

Visible differences in the bands on the picture can also arise from time-base variations. These may be caused by "quadrature misalignment" or by differences between the tape-to-head relations in recording and the replay relations.

If a tape is recorded on a drum whose heads are spaced precisely 90° apart and then played on a drum whose heads are unevenly spaced, the picture contains displacements of vertical picture elements. Certain bands are wider than others. These represent the output of heads which track more than their share of the time because of their greater angular separation from their successors.

This effect must be reduced to the point that misalignments are less than noticeable, if detectable at all. Although the Standards of Good Engineering Practice[1] suggests that such errors should not exceed 0.5 per cent of the line interval, or 0.3 μsec, so large an error is objectionable to viewers. Error actually *must* get down to about 0.1 μsec and in practice should be held to half this value. Since the heads operate at approximately 1,500 ips, 0.05 μsec of time corresponds to 38 μin. of tolerance; this is normally achieved in production heads, which are first aligned by machine methods to within ⅔ mil of correctness and then are brought within final precision, ±38/1,000 mil, by observation of the picture with adjustment and readjustment of tapered screws fitted into slots in the drum. These screws are wedges to increase or decrease the spacing between the four segments of the drum. The factory supplies precision-recorded tapes with which quadrature of any head can be checked against standard and, if necessary, adjusted in the field.

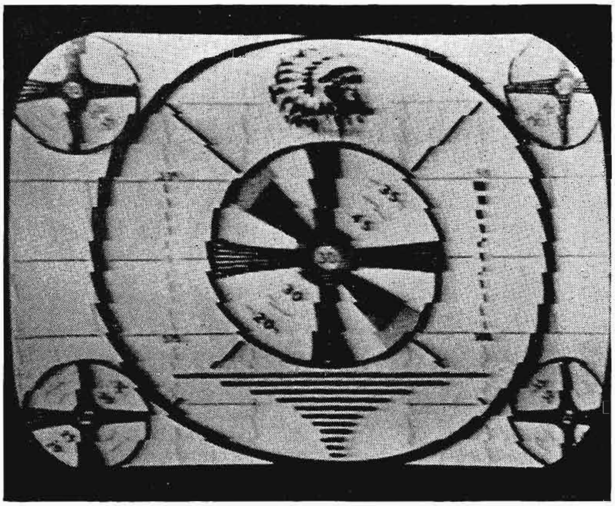

FIG. 5-11. Guide too close to head.

There are *several* ways in which the relation of the tape to the drum can vary. This relation is determined by the position of the vacuum guide with respect to the drum; by the effective diameter of the heads, which varies with wear; and by the vacuum applied.

In operation the vacuum is held constant, and an adjustment is provided for the lateral position of the guide. When the guide is moved close to the drum, the tape is stretched more in a direction transverse to its linear motion. Thus the tracks are lengthened slightly. If the guide is backed away slightly, the tape will be stretched less and the tracks will shorten. This makes it possible to tolerate the changes in the effective diameter of the drum which takes place as the heads wear down. But misalignment is possible at will.

If the guide is moved in playback so close in to the drum that the tracks are stretched longer than they were in the recording process, vertical picture elements will be slanted in each band, producing the "venetian blind" effect. This is readily remedied by backing off the guide, and in production models adjusted to maintain a standard track length, the process is automatic by means of a servo system which controls the position of the guide.

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[1] See Part 3, FCC Rules and Regulations.

It is desirable, of course, that the contour of the female guide should be perfectly concentric with the axis of the drum. If it were not, the pressure on the tape at the part of the guide closest to the drum would be higher than that elsewhere, on each sweep of the heads, and wear on the tape would be uneven. But assuming this could be tolerated, small displacements of the guide upward or downward would not matter so long as the tape always were played back on a head assembly misaligned in the same manner. Picture defects appear only when a tape is played back on a machine whose vacuum guide is aligned differently from that on the recording machine.

If a recording has been made on a perfectly concentric drum and guide, then played back on an assembly whose guide is adjusted too high (see Fig. 5-12), the velocity of the head, with respect to the original track, is not constant throughout one sweep across the tape. The tape is stretched *less* at the top and *more* at the bottom of the sweep.

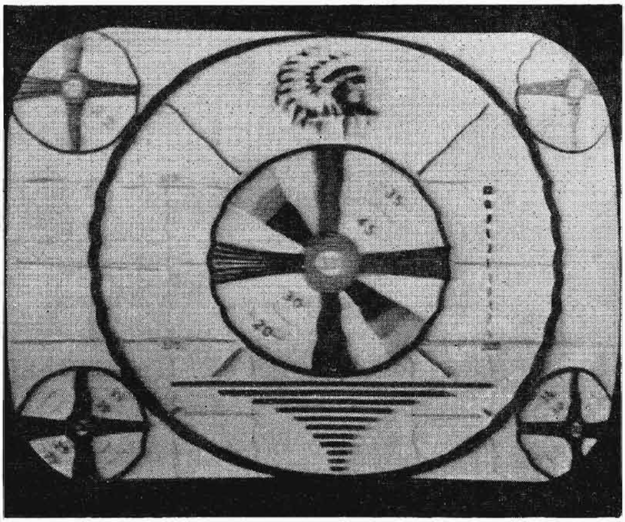

FIG. 5-12. Guide too high.

The result of adjusting the vacuum guide too high is curvatures of vertical picture elements, or scalloping. Adjusting the guide too low will result in scallops rounded to the right. This effect can be prevented in interchanging tapes by adjusting all vacuum guides to a common height with respect to the drums. The position should be as nearly as possible concentric with the axis of the drum. The easiest way to accomplish this is to adjust all assemblies correctly at the factory and then to use standard tapes periodically in the field to check maintenance of the setting.

Larger dimensional errors are tolerable in vertical misalignment of the guide than in horizontal or quadrature misalignment. For example, if the vacuum guide is vertically displaced 1 mil in playback with respect to the position of the guide used in recording, the maximum scalloping excursion will be 0.3 μsec on the screen. Scalloping is not detectable at 0.1 μsec, so vertical positioning of the vacuum guide need be held only to a few tenths of a mil, plus or minus, to obtain satisfactory results. This is easier than obtaining the microinch tolerances which apply to quadrature, especially because the same magnification of the effect is obtained by using the picture as a micrometer.

All the factors which govern the interchangeability of tapes on VR-1000 monochrome recorders are, thus, under adequate control, and means exist through the use of standard tapes and available adjustments to keep these factors under control in commercial broadcast operations.

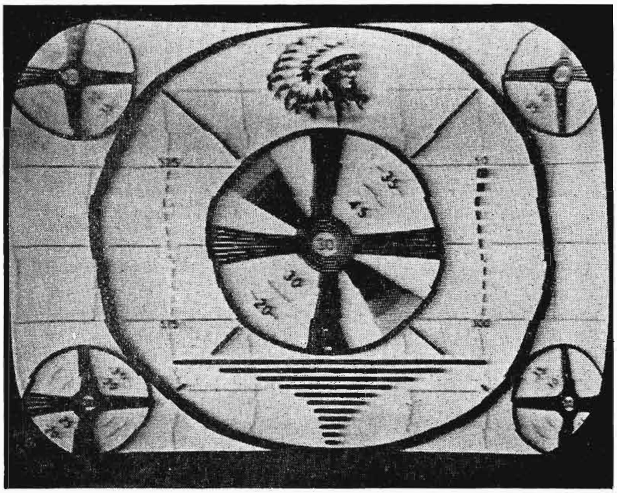

FIG. 5-13. Angular misalignment of heads.

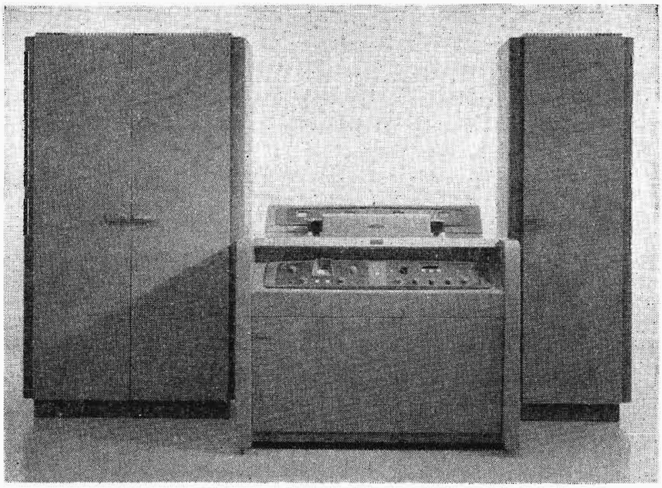

FIG. 5-14. Color TV tape recorder. Identical with its monochrome counterpart in every way, except for the addition of a rack of color electronics, the color TV tape recorder will handle either color or monochrome tapes.

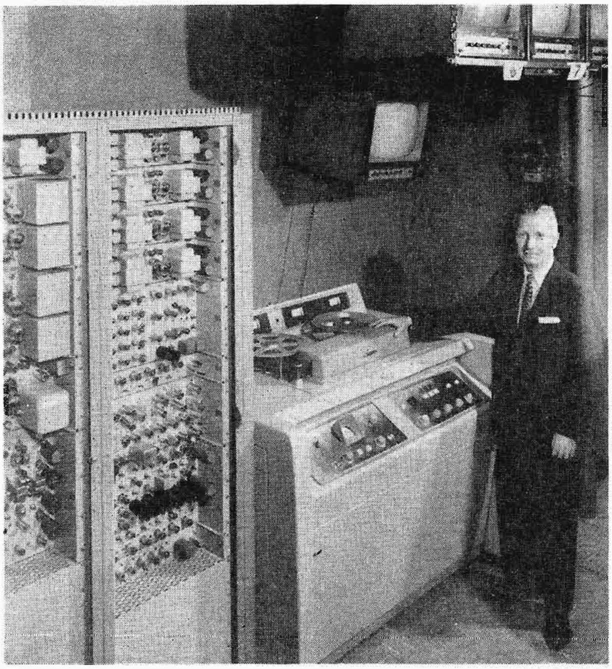

FIG. 5-15. Typical TV tape recorder installation (KGW-TV).

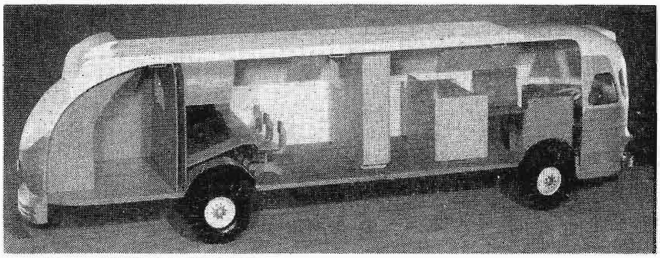

FIG. 5-16. Mobile TV tape system. The model shown here illustrates the manner in which one bus was outfitted as a mobile TV system, complete with tape recorder.

FIG. 5-17. A TV tape cruiser. Containing one video recorder, three cameras, centralized control facilities, and more than 10 kw of power-generating equipment, this air-conditioned cruiser covered more than 12,000 miles during the summer and fall of 1959, making recorded TV tapes "on the go" and on location.

THE FUTURE OF TV TAPE

Late developments, including equipment which intersynchronizes two TV tape machines in playback with a synchronizing generator, or with one another, and other new devices all make it clear that expansion is certain for the usage of TV tape in television broadcasting. The intersynchronizing device makes it possible to fade, wipe, lap-dissolve, or cut from tape-to-tape, tape-to-live, live-to-tape, tape-to-film, film-to-tape, tape-to-network, or network-to-tape. Thus, the TV tape recorder is now capable of producing all of the same effects which can be achieved in live TV, with the "hindsight" advantage possessed only by prerecording.

Syndicated TV tape programs are expanding in number and usage, and the entry of one or more of the large TV program producers, formerly exclusively users of film, into the syndicated tape market assures that programming on tape will not be confined to "target of opportunity" programs, produced by local stations only, but will expand to include name-star shows as well.

Commercials, prepared and distributed on tape, now make up a substantial portion of all national spots and network commercial inserts. Lower cost of production and live-quality reproduction account for this growth and will assure further expansion.

The growth of color will be stimulated by tape and will stimulate further use of tape. Since the recording medium is the same, whether the recording be in color or in monochrome, and since medium costs for color film are considerably higher than for either monochrome film or tape, the use of tape in prerecorded commercials, programs, and news events in color is sure to expand. While interchangeability of color tapes requires more exacting conformity to standard adjustments of the machines, it has been demonstrated to be commercially attainable and can be expected to become still easier.

Part 6

TV FILM HANDLING AND PROCESSING

NAB ENGINEERING DEPARTMENT [*]

INTRODUCTION

General Information of Interest

Film plays a very important part in the program structure of the television station. When you consider that the "air time" of the average television station is between 30 and 40 per cent film, it then becomes apparent that as much sound planning and thinking is required in providing adequate facilities for handling this important program source as that of any other department in a television station.

In order to attain optimum television broadcast reproduction of 16-mm sound on film, the film prints should conform to the technical requirements of the television system.

Although many of these requirements do not differ from those necessary for good-quality theatrical prints, there are a number of requirements that are peculiar to television only.

Film prints intended for telecast should not exceed a density range of 1.5. Within this range, the significant highlights should not exceed a density of 0.4 and the shadow or dark areas should not have a greater density than 1.9. Although some slight overall shift of these densities can be made toward the toe of the print curve, the 1.5-density range between minimum and maximum scene densities must be maintained. It must also be remembered that in the toe portion of the curve, highlight density distortion increases as the base density is approached, and the characteristics of the print emulsion should be carefully appraised before any shift of important scene densities is made into this region.

Films primarily made for television use (*Life of Riley, The Loretta Young Show, Fireside Theater,* etc.) fulfill the density requirements for good telecast exhibition. However, film prints of motion pictures originally made for theatrical exhibition that have been reissued on 16-mm stock for television, in most cases, are printed on standard release positive to approximately the same density range as release prints intended for theatrical use. This density range is excessive for the television system and results in substantial losses in both shadow and highlight areas of the picture. Western feature films having simulated night scenes (made in daylight on infrared film with appropriate filters) printed on normal release positive stock are notable examples of prints with excessive density ranges.

Printing such prints "two printer lights lighter" than is customary for theatrical prints does little to make these prints acceptable for television use. While little can be done to make "soot and whitewash" infrared scenes acceptable for telecast, retiming of originals for printing on low-contrast release positive, together with proper process-

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[*] Compiled from sources listed at the end of the chapter.

ing for this type of emulsion, will do much toward making most theatrical feature films conform more closely with television print density requirements.

However, having a film print with a satisfactory brightness or density range for the television system is not enough. All prints can, and all too frequently do, exhibit a variety of defects and imperfections that individually or collectively make the film print unsuitable for good television reproduction.

Vertical or horizontal unsteadiness of the print image will cause serious loss of definition when such a print is reproduced through the television system. For this reason it is essential to prevent image unsteadiness during the shooting and printing stages of the film and to exercise extreme care in the handling and use of these prints so that the film edges and perforations will not become worn or damaged.

Scratches, abrasions, and dirt, whether on the film surfaces or imprinted in the emulsion, cause a loss of picture definition and are generally distracting to the viewer. Such defects or imperfections appear as "noise" in the telecast picture. When similar picture defects occur during "live" local or network shows, it is indicated to the viewer that a "technical difficulty" exists. These technical difficulties that develop in the electronic system and impair the picture quality are infrequent, unforeseen occurrences, usually of short duration. Whenever they occur, the station is quick to declare the difficulty and apologize to the viewer for the poor picture quality. Since the quality of all film prints can be determined before telecast, the airing of defective or poor-quality film prints seems inexcusable and entirely inconsistent with good operational practice.

Cue marks and splices are similarly disturbing both to good picture quality and to the viewer. Although the use of visual cues has long been standardized for theatrical motion pictures, no such standardization seems possible for television, since film programming requirements differ at each station.

Accurate timing of film is easily accomplished. The use of the clock for getting "in" and "out" of films at indicated times rather than by the use of visual cues seems to make for a more satisfactory film operation.

When visual cues are used, operational hazards are increased by the number of cue marks present in the film. With the "timed method," the clock provides the operator with a positive reference check at all times and, of course, obviates the necessity of mutilating the film print with numerous sets of cue marks.

Splices, whenever necessary (and few should be necessary in any program film print), should be narrow, well made, and straight across the film.

A $\frac{1}{16}$- or 0.07-in. straight splice, carefully made, is entirely safe and satisfactory for projection use. Intermittent sprocket and continuous pull-down projectors pass these splices more easily than the heavier $\frac{1}{10}$-in. splice.

Because of the scanning ratio of the television system to the projected film image, diagonal splices should never be used.

Few splices should be necessary in any film. Half-hour syndicated program films with commercial spot films spliced in will usually necessitate 8 splices at most. (The splice at the head and tail leaders into and out of the film is not counted.) However, if such a film has more than 12 splices, including the splices for the commercial spot films, there is a good chance that the continuity of the sound track may be interrupted and that there will be evidence of other defects which will make the print unsuitable for good television reproduction.

Films with damaged sprocket perforations or films that have cuts, nicks, or tears in either side of the film are also unsatisfactory for telecast. Prints with "notched-out" sprocket perforations are unsafe for television projection regardless of how well the projectors will usually pass such film. There is the ever-present possibility of an edge of such a perforation getting caught or buckled in the feed or intermittent sprockets and causing a film stoppage.

Roughness of the guided edge is generally due to nicks, cuts, or tears and, however slight, defeats film steadiness in the gate. As noted earlier, any unsteadiness of the projected image will cause loss of definition in the telecast picture.

Sound quality of a film print is no less important than the picture quality. In addition to having a constant sound level throughout the print, the sound track should have a good frequency range, have a good signal-to-noise ratio, be free of distortion, have the correct track for the picture, and be synchronized with the picture.

The frequency range of a good optical sound track should run from 60 to at least 6,000 cps with a signal-to-noise ratio at least 50 db down. Intermodulation distortion should not exceed 5 per cent.

It is not impossible for a film print to have the wrong sound track, and all too frequently prints with the correct track are found to be out of "sync" with the picture. Although prints having either of these defects should be detected at the laboratory, there is considerable evidence that these defects escape detection not only there but by the distributor and a number of exhibitors as well. For correct "lip sync," the sound track must be synchronized 26 frames ahead of the picture.

The sound-track area must be free of surface or imprinted scratches, abrasions, and dirt. Because 16-mm sound film has sprocket perforations on one side of the film only, pressure contacts are incorporated into most projector gates which contact the film between the picture and sound-track areas and also on the outer edge of the print. Often emulsion particles build up on these contacts, and the film becomes marked or scratched at these points. If these scratches or markings remain narrow and between the picture and sound-track areas, no harm is done. However, if they extend into the sound track, serious distortion and noise result.

Care and Cleanliness

Film is delicate and should receive careful attention at all times. Just as in an instantaneous recording, a certain degree of deterioration occurs each time the film is used. The exact amount depends entirely on the treatment it receives in projection, rewinding, previewing, handling, and shipping. To produce good pictures, cleanliness is a *must*. As it is projected and rewound (because of certain atmospheric conditions), a static charge will build up on the film and it actually becomes a magnet for the attraction of dust and dirt particles. Therefore, wherever film is handled in the station, it should be kept as clean and dust free as possible.

When negatives or prints become dirty or badly oiled, they should be properly cleaned before being placed in storage or in use. As mentioned previously, film should not be cleaned by passing it through a dry cloth because of the danger of scratching by dirt particles accumulated in the cloth. Cleaning can best be done by a motion-picture film laboratory, where suitable cleaning machines are available and proper techniques and precautions can be observed.

When prints must be cleaned by hand, the work may be done by rewinding the film slowly through a lint-free rayon plush or soft cotton cloth pad which has been moistened with film-cleaning fluid. The pad can be folded over the film and held in the left hand while the right hand is used to operate the rewind. The operation should be carried out slowly so that the cleaning liquid can evaporate from the film before it is wound into the roll. The pad surface must be changed frequently, since a dirty pad will redeposit oil and dirt and may abrade the film. Where large quantities of film are to be cleaned by machine, it is desirable to arrange to feed a length of cleaning pad slowly through the device so that as it becomes dirty, a clean area is automatically provided.

The cloth used for cleaning must be selected carefully. Best of all is a clean, short-nap rayon plush or velvet. Next best is a soft cotton canton flannel, knit fabric, or plush. Cotton batiste and nainsook are also used, although they do not absorb dirt so well or hold it away from the film. Baled rags should not be used, as these usually contain many harsh cloths that will scratch and abrade the film and may also contain a great deal of lint. It is false economy not to use new cloths specially selected for the job.

There are a variety of organic solvents or fluids which might be used for cleaning film. The requirements of a good film cleaner are rather exacting, however, and relatively few materials are fully satisfactory. These requirements include not only cleaning ability but such factors as freedom from toxicity and flammability, a suitable evaporation rate, effect on film base and equipment, cost, etc. Several solvents which have been used for cleaning motion-picture film are compared and described below.

Carbon Tetrachloride—Not Recommended

Carbon tetrachloride has been used a great deal in the past for cleaning motion-picture film but is not recommended because of its great toxicity. Carbon tetrachloride fumes are poisonous. Headache and nausea are a first warning, and *continuous exposure may be fatal.* Evaporation of only two teaspoonfuls of carbon tetrachloride into a small, unventilated film-inspection room is enough to raise the concentration of fumes beyond the safe level. Carbon tetrachloride is dangerous whenever the odor becomes strong enough to be obvious. If it is used for cleaning film, the ventilation must be good enough so that a person just entering the room where carbon tetrachloride is being used can barely smell the fumes. If the fumes become stronger, all windows should he opened, the cleaning stopped, and the room emptied until it has been thoroughly ventilated.

n-Heptane and Freon-113. A Mixture (1 to 1) Is Recommended

n-Heptane alone is highly flammable and should not be used, but if it is diluted with equal parts of Freon-113, a mixture is obtained which is considered safe to use. Its flammability is only moderate, and its toxicity is slight. Freon-113 alone is nonflammable and perfectly satisfactory for cleaning film but is rather expensive.

Inhibited Methyl Chloroform—Recommended

Methyl chloroform is much less toxic than carbon tetrachloride but is still "moderately" toxic and should be used with care. Fumes of methyl chloroform should not be breathed for any length of time. It should not be used without adequate venting or ventilation.

Methyl chloroform has no harmful effect on either black-and-white or color films when used as recommended for cleaning. However, contact of film with methyl chloroform for 15 min or more may cause an increase in curl, particularly with acetate propionate or acetate butyrate base. It is therefore important that the solvent evaporate completely before the film is wound up. This usually requires only a second or two. Methyl chloroform should not be spilled on Tenite plastic cores because of its softening action.

Methyl chloroform without inhibitor attacks aluminum, zinc, and their alloys with rather a vigorous chemical reaction. It is, therefore, necessary to use only inhibited methyl chloroform for cleaning film in case aluminum parts may be used in the equipment. Most commercial methyl chloroform customarily contains an inhibitor, but this should be definitely ascertained before using. Both Eastman Kodak methyl chloroform used in film cleaners and lubricants and Dow Chemical Company Chlorothene grade of methyl chloroform contain inhibitors which have been tested for inactivity toward film.

A word of caution is necessary in regard to cleaning lacquered film. Cleaning solvents may dissolve certain lacquers used on film and may result in streaking from incomplete removal of lacquer. Unless the lacquer properties are known, it is best to try the cleaning solvent on an end of the film first.

Removal of Fungus Growth

Water or water solutions should not be used for the removal of fungus growth from color or black-and-white films because, in the great majority of cases, fungus growth on the emulsion side causes a solubilizing of the gelatin. The use of water or water solutions will lead to disintegration of the image.

The film should be cleaned by wiping it with soft plush, cotton, or chamois skin moistened with an approved film-cleaning liquid, as described in the previous section. Such a treatment will remove most of the surface growth. The idea is to rub off fungus growth, dirt, grease, etc., with a buffer wetted with any of the suggested fluids. The use of a fluid is suggested as a means of carrying off the dirt, washing out any debris that may be held in indentations, etc., and acting as a sort of lubricant to prevent excessive scratching that would result from the use of a dry buffer.

When the gelatin has become etched or distorted by the fungus growth, there is no satisfactory method of restoration. If films are lacquered, the etching effect caused by fungus will be greatly minimized. If the lacquer is damaged, it can be removed and fresh lacquer applied.

Space Considerations

Space requirements for handling film will vary with the station installation. However, there are two focal points in planning film facilities: (1) the projection room and (2) the area required for inspecting and previewing film. In the projection room, adequate space should be provided for editing, splicing, rewinding, commercial insertion, and daily storage for shows that are to be aired. Just as in any other line of business, permanent storage is always a serious problem, and perhaps a good rule to follow is to double whatever your estimated space requirements might be. This really is not so foolish a statement as it might at first appear. Some film suppliers have initiated a procedure useful to themselves, but it may present a real problem to you. They will often advise you to hold film and ship upon receipt of their advice. However, it usually turns out that a considerable length of time has elapsed and you are left with the filing problem. So it is a good practice to return every foot of film that you do not own or do not intend to use in the very near future.

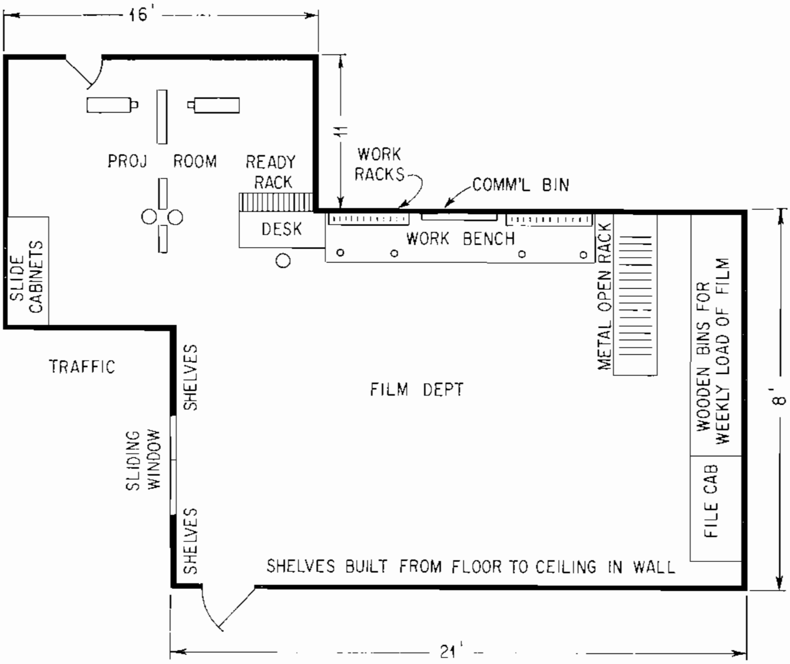


Fig. 6-1. KSBW-TV film and projection facilities.

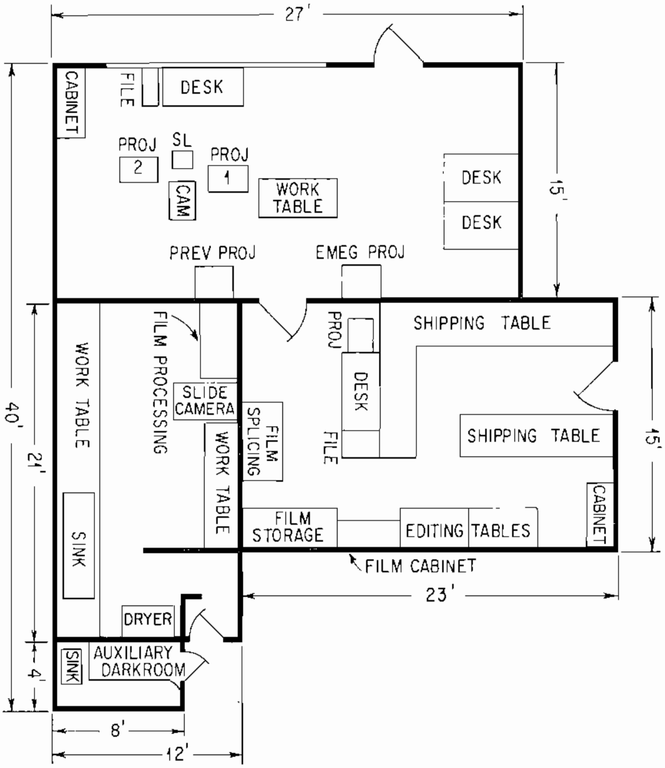


Fig. 6-2. WMT-TV Film Department and processing facilities.

Editing Area

An editing area should be situated best to accommodate last-minute, hurry-up changes so frequently encountered in the preparation of film for airing. The actual design of the editing table or bench will depend on local conditions and the particular likes and dislikes of the operating personnel. However, the following basic equipment will be needed:

One film splicer
One pair rewinds
One measuring machine
One small viewer
One editing table or bench
One 2- by 2-in. slide-file cabinet
One 3¼- by 4-in. slide-file cabinet
One open-face rack for storing large reels that will be aired during the day
One permanent-type storage cabinet
Twelve 2,000-ft flat steel reels
Twelve 1,600-ft flat steel reels
Twelve 400-ft flat steel reels
Fifty 100-ft flat steel reels
1,000-ft blank leader
One 14-in. steel rewind flange
One small screening projector
One 34- by 50-in. screen on tripod or wall mount

These are minimum requirements, and larger operations will call for larger quantities of the various items.

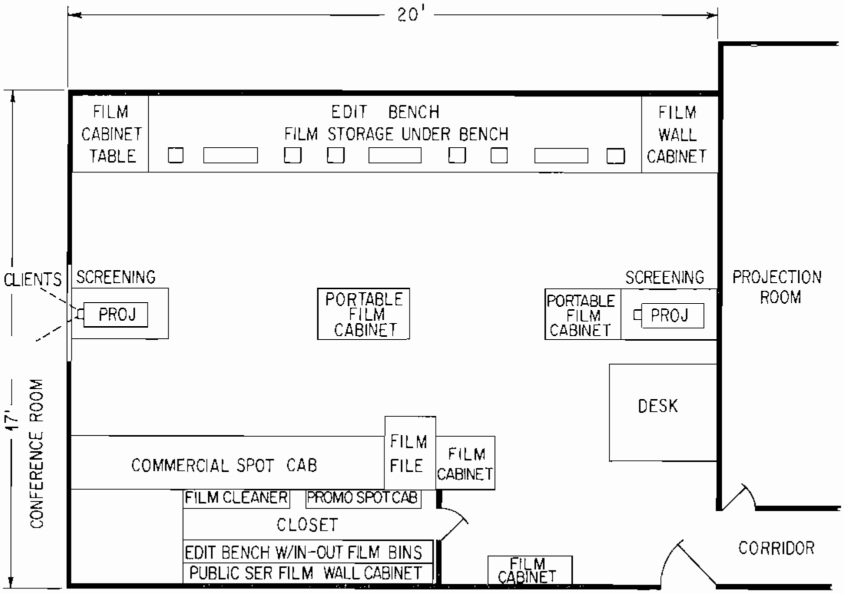


FIG. 6-3. WFMY-TV Film Department facilities.

Film-equipment Accessories

A word now about some of the film-equipment accessory items that are needed in the successful handling of film in a TV station.

Film Splicer. This instrument is used to splice film and should be considered as a precision instrument. A word of caution about film splicing! One faulty splice can cause a show, commercial, or presentation to be either a success or a "flop." Even though time is important in a television station, *there is no short cut to making a splice in film.* There are certain basic operations to be performed, in the proper order, and a definite amount of time is required to make a good splice. Faulty splices can usually be traced to dirty splices, incomplete removal of emulsion, wrong kind or old cement, improper adjustment of splicer, and insufficient drying time of the splice.

Scraping Tools. The usual instruments used in scraping off the emulsion of the film to be spliced are single-edge razor blades, emery board, and various types of commercial scrapers. Double-edge blades should never be used.

Film Cement. This is used in cementing the splice together after it has been prepared for splicing in the film splicer. It should be placed in a handy applicator bottle and when not in use kept tightly sealed. If the cement is allowed to become exposed to air for a period of time, its adhesive properties are destroyed and weak splices are sure to result.

Small Viewer. This is used for "quick" editing and is very handy for previewing short sequences, interchanging spots or scenes, and checking continuity of film strip or show.

Rewinds. Most TV projectors do not incorporate automatic rewinding mechanisms, so these, of course, are needed for rewinding film after it has been aired and for editing purposes.

Footage Counter. This is used for accurately measuring the time of a spot or any length of film. Previewing projectors are not normally equipped with sync motors, and accurate timing cannot be secured by projecting and timing with watch or clock. A 16-mm sound film is projected at a speed of 36 fpm, and by measuring the length of the film on the footage counter, it is easy to determine the exact amount of time it will take to "air" the film.

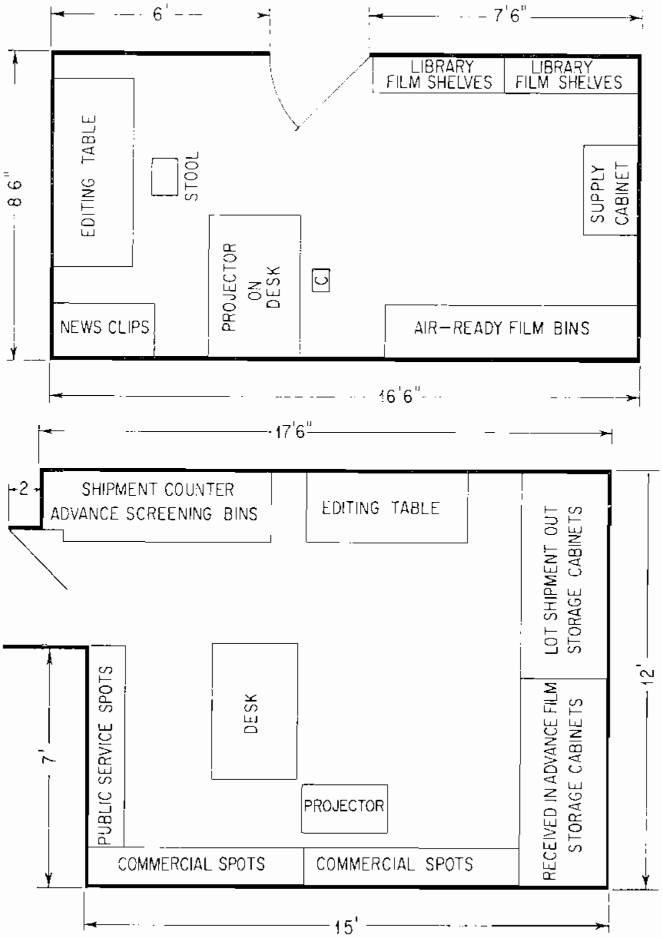


Fig. 6-4. WSPD-TV film editing room (above) and film shipping room. Facilities also include Film Department office and on-air projection room.

Daily Storage Rack. Some form of rack must be provided in the projection room for the temporary storage of films to be "aired" daily. This rack should be able to accommodate at least a week's film supply. A very good method is to set up the file according to days of the week. This will enable the scheduling department to keep ahead of projection and save a frantic hunt at the last minute for a film that is to be aired immediately.

Slide-storage Cabinet. A filing cabinet to accommodate both 2 by 2 and $3\frac{1}{4}$ by $4\frac{1}{4}$ slides must be provided in the projection room for storing slides used every day or even occasionally.

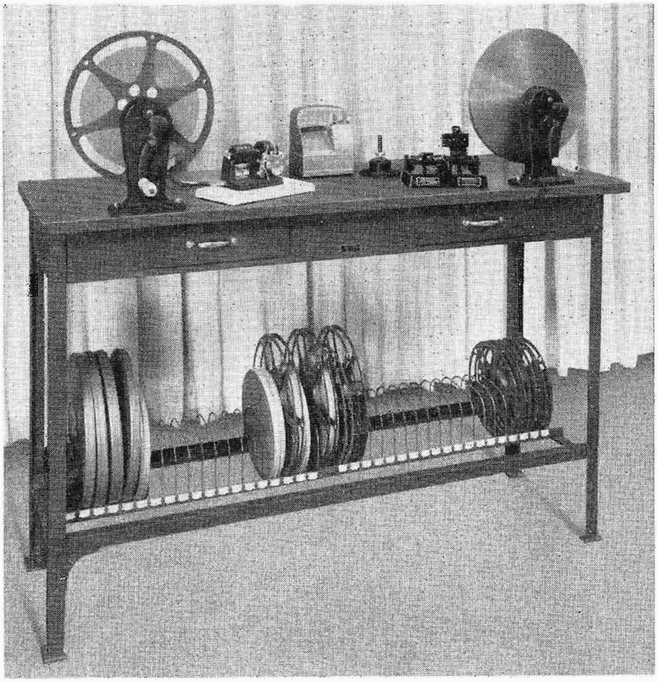
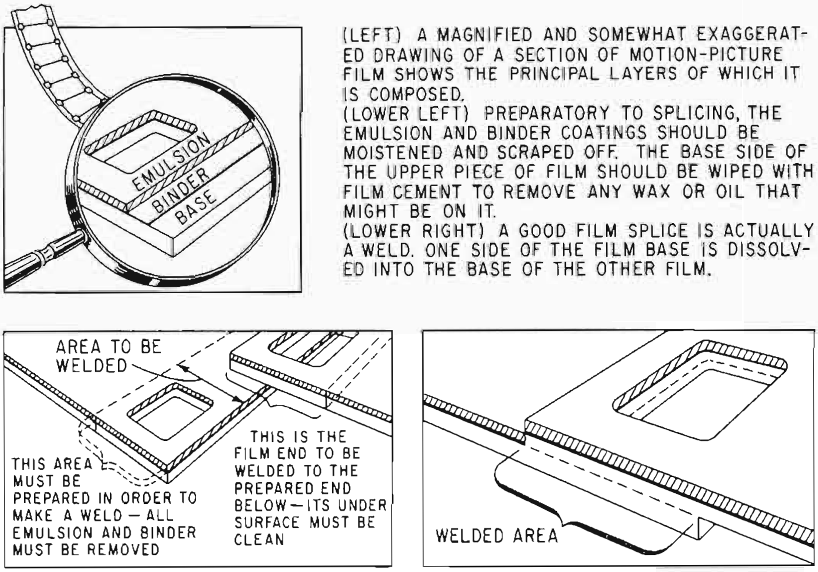


Fig. 6-5. View of a typical TV film-editing bench setup for television stations. Note that rewinds, splicer, viewer, and measuring machine are needed.



(LEFT) A MAGNIFIED AND SOMEWHAT EXAGGERATED DRAWING OF A SECTION OF MOTION-PICTURE FILM SHOWS THE PRINCIPAL LAYERS OF WHICH IT IS COMPOSED.
(LOWER LEFT) PREPARATORY TO SPLICING, THE EMULSION AND BINDER COATINGS SHOULD BE MOISTENED AND SCRAPED OFF. THE BASE SIDE OF THE UPPER PIECE OF FILM SHOULD BE WIPED WITH FILM CEMENT TO REMOVE ANY WAX OR OIL THAT MIGHT BE ON IT.
(LOWER RIGHT) A GOOD FILM SPLICE IS ACTUALLY A WELD. ONE SIDE OF THE FILM BASE IS DISSOLVED INTO THE BASE OF THE OTHER FILM.

Fig. 6-6. A graphic illustration of the elements that go into a good splice. Reproduced, with permission, from the copyrighted Kodak publication "Industrial Motion Pictures."

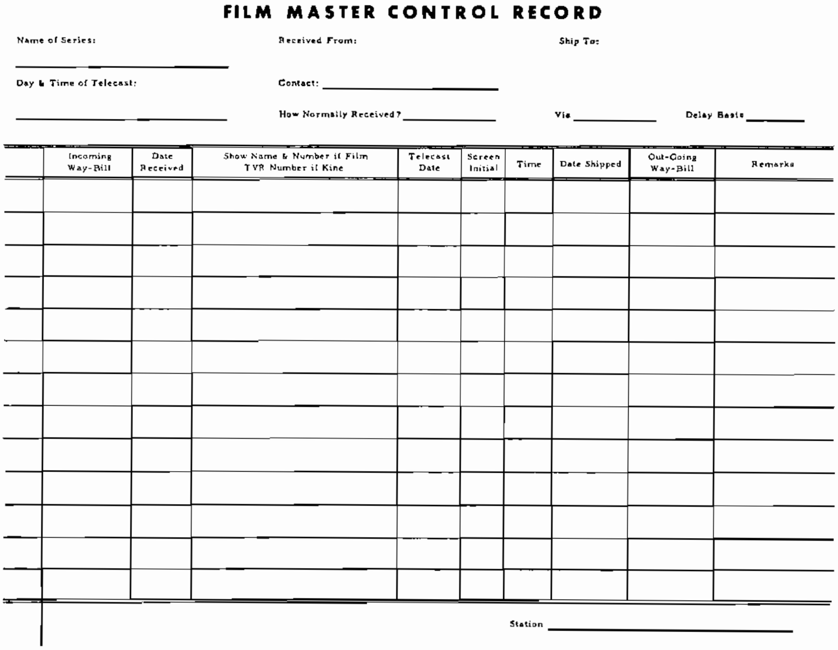
"Screening" or Previewing

Volumes could probably be written on the subject of whether film should be previewed before it is aired. However, in pointing out some of the things that *have* happened and omitting many things that *could* happen, it will at least stimulate your thinking, and the decision rests with you as to whether film should be inspected or previewed before it is aired. Even today, stations receive film that is patched together with tape. You obviously are aware of what happens when you try to run a tape slice through a projector. It just won't work. Brand-new prints have been received with the sound track printed backward, wrong sound with wrong picture, picture printed backward, torn sprocket holes, commercials left in by the previous station, and many other difficulties too numerous to mention. In other words, you can't tell what the film is or its condition just by looking at it on the reel. It is suggested that some method of inspection or previewing be set up in your station. A complete previewing report form should be filled out for each film, listing all the necessary data that would be required by the Sales and Program Departments.

If space is provided for screening and previewing film, a small projector and screen will be necessary.

Scheduling Commercials

Just as in radio broadcasting, an accurate system must be used in scheduling spots. In TV the spots appear in the form of 10-sec, 20-sec, and 1-min lengths of film. If not furnished by the agency or supplier, leader must be spliced to these short lengths of film so they can be threaded in the projectors. Scheduling must provide all parties concerned with the proper information as to whether a spot is to be tacked on the head or tail of a certain show or run individually.



FILM MASTER CONTROL RECORD

Name of Series: ____________

Received From:

Ship To:

Day & Time of Telecast: ____________

Contact: ____________

How Normally Received? ____________

Via ____________

Delay Basis ____________

	Incoming Way-Bill	Date Received	Show Name & Number if Film TVR Number if Kine	Telecast Date	Screen Initial	Time	Date Shipped	Out-Going Way-Bill	Remarks

Station ____________

Fig. 6-7. One of the many types of film shipping and filing records developed by stations.

Receiving and Transshipping

A responsible party should be assigned these duties; they are important. An accurate receiving and transshipment record should be made on all film and should contain the following basic information: date, time received, source, type, postage paid or collect, disposition after airing, person receiving film, whether mounted on reel or core, shipping case, etc.

You will receive film from many sources. Most commercials will come from the advertising agencies or their suppliers directly to you. (In some cases, the client will furnish it.) Films will be in various quantities and physical size. Some of them will be tied together, and it will be necessary for you to break these down, place them on small reels, catalogue them, and file for future reference. Others will come to you individually on plastic cores or sometimes on small 100-ft reels. A word about reels, especially the larger size, is appropriate. Inaugurate this rigid policy at the very beginning:

FIG. 6-8. Since films are expensive, a good sturdy shipping case is suggested.

1. If you receive a film on a plastic core, ship it back on a plastic core after you are finished with it.
2. If you receive a film on a reel, ship it back on the same size reel after you are finished with it.

Reels are expensive! In other words, if you receive a film on a plastic core and ship it back on a professional reel, *you* lose. Over a period of a year, this can amount to a very sizable figure.

Under the present system of bicycling kinescopes, the following procedure is fairly well established by now. The network or originating station will film the show and release to various stations throughout the nation for a delayed play date. The network will advise each station where it should forward the film after it has "aired" the film and from what station it will receive its next film. So remember that you are just as dependent on a station for getting your show in good condition and on time as it is dependent on you for the same service. This is a responsible duty, and conscientious personnel should be selected to supervise these duties. Many packaged shows and "kines" are open-ended, and space is allowed for insertion of local cutins or individual commercials. Needless to say, it is extremely important to see that the show leaves you in as good or better condition than you received it.

Mailing Charges

This brings us to the subject of express or mailing charges, which is an important item. For the film operation of an average station, the express charges for film directly chargeable to program expense will run between $5,000 and $7,000 per year. When you consider that kind of expense, the need for constant vigilance is apparent in selecting air express vs. regular express. Check and recheck your play dates, and whenever possible, ship and order all film to be shipped by regular express.

Slide-making and Film-processing Facilities

The local advertiser, along with many national accounts, cannot incorporate in their advertising budgets the price of having commercials made by a professional 16-mm producer. The average price of a 1-min, sound-on-film television spot made by a 16-mm producer is between $250 and $1,000 or more, depending on the type of spot desired. This means that the advertiser will turn to the television station operator for an economical answer. The station which can provide slide- and film-processing facilities will be in a better position to sell the air time. It is another instrument to help the Sales Department in providing a complete customer service and will help lower sales resistance. This is especially true with slides. Virtually every commercial or show will require very frequent changes in slides. Slides are inexpensive to make and if handled properly can provide the station operator with an additional source of revenue.

As mentioned previously, handling film in a television station is not difficult, but it does warrant serious preliminary planning in laying out the facilities.

Laboratory Practices on Films for Television [1]

These recommended laboratory practices on films for television are intended as a guide for both producers and laboratories engaged in production and processing of such films.

The recommendations contained herein are based on a committee survey of the literature and answers to a questionnaire sent to numerous people engaged in production, laboratory, and television operations.

Black and White

Photography and Lighting for Optimum Quality from Film. Any recommendations for laboratory practices on films for television should include certain recommendations for photography, lighting, and production. The laboratory can achieve the best results with the aid and cooperation of the people in these fields.

1. Negative (or reversal original) should be neither underexposed nor overexposed, as set forth in film manufacturers' recommendations. This is particularly important when the faces or essential shadow detail are unavoidably at extremes of the brightness range.

2. The use of close-ups and medium camera shots with only infrequent use of long shots is recommended. Wide-angle shots and long shots should be used only to establish perspective.

3. The ratio of key to fill lighting should be kept within the range of 1½ to 1 and 2½ to 1. The maximum brightness contrast in the scene, as read by reflectance meters, should preferably not be greater than 20 to 1 but in any case should not

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[1] Taken from "Laboratory Practices on Films for Television" by The Association of Cinema Laboratories, Inc., Washington, D.C.

be greater than 30 to 1. Uniformity of fill lighting throughout the scene is advisable.

4. Night effects should be achieved by proper use of lighting and set arrangement, instead of requiring the printing down of day scenes for night effect, which is sometimes done for theatrical use.

5. Large areas of either white or black or any uniform density are not advisable.

6. Backgrounds for titles, trademarks and inserts should not utilize large expanses of uniform, unbroken density, especially if the background is either very light or dark.

7. Cutting back and forth between scenes where the background is alternately dark and light should be avoided. Alternate camera angles in a given sequence should have similar background brightness.

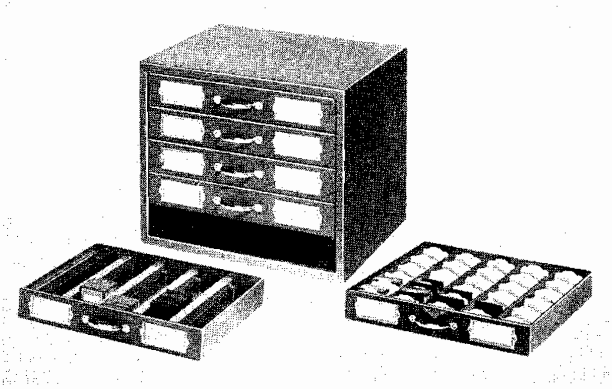

FIG. 6-9. The careful and orderly filing of slides in cabinets like the above is recommended.

8. Scenes should be composed and lighted so that there is always something in the scene lighter than the face or point of interest and, if possible, something darker than the face.

9. Camera apertures should cover sufficient frame area to be as large or larger than the television transmitted area. All important action should take place within the "safe-action area." All titles and other written material should be kept well within the "safe-title area." These areas are as follows:

	Transmitted area, in.	*Safe-action area, in.*	*Safe-title area, in.*
35 mm	0.792 wide by 0.594 high	0.712 wide by 0.478 high	0.621 wide by 0.466 high
16 mm	0.368 wide by 0.276 high	0.331 wide by 0.248 high	0.288 wide by 0.216 high

The recommended aperture size for the review room projector is 0.746 in. wide by 0.531 in. high, with rounded corners.

The safe-action area and safe-title area are those areas which will be seen on the majority of home TV receivers. Titles or important action should not extend into the corner areas, as these areas may be lost owing to the oval shape of some receiver masks.

Original Negatives. These should be developed to a normal Ib gamma of 0.65 to 0.70. The IIb gammas for a given Ib gamma will vary with film stocks and developers. Negatives should be free of excessive abrasion, dirt, drying streaks, and water spots within the laboratory control. Negatives should be developed with sufficient agitation so that directional effects are minimized.

Master Positives (Fine Grains). These should be developed to a normal print gamma of 1.4 (as read by the print-through method[2]) and should be printed so that the minimum highlight density is above 0.90. This density specification applies to all present emulsions. Introduction of new films now contemplated for this purpose could lower this value because of a lower toe break in the H & D curve.

Dupe Negatives. These should be developed to a control gamma which will reproduce the contrast and gray scale of the original negative. On contact dupes, this is approximately a gamma of 0.65 as read by the print-through method. On optical dupes, this is approximately a gamma of 0.55. Negatives should be free of excessive abrasion, dirt, drying streaks, and water spots. Negatives should be developed with sufficient agitation so that directional effects are minimized.

Prints. Prints should be made on a positive stock and developed to a print contrast as required by the photographic contrast of the negative to be printed.

Where the negative is of consistently low image contrast, it can be printed and developed at the normal gamma of approximately 2.35 (gamma as measured by the print-through method). Where the contrast of the negative is of consistently high photographic contrast, it would benefit by being printed and developed to a lower print contrast, which may be as low as a gamma of 1.85 (gamma as measured by the print-through method). This contrast can be achieved by development of films such as Eastman fine-grain release positive film, type 5302, or Du Pont type 825 fine-grain release positive film to a lower than normal theatrical contrast or the use of low-contrast positive films such as Du Pont type 824 fine-grain low-contrast positive film or Eastman fine-grain duplicating positive film, type 5365, developed in a normal positive developer.

In the timing of prints, it is recognized that the printer lights for the numerous scenes comprising an edited film are selected from cinex tests or by visual evaluation of the negative. The resulting print intended for telecasting should appear somewhat higher in density in the highlight areas and somewhat lower in contrast than prints customarily intended for theater projection.

In prints thus timed with proper scene-to-scene balance, the majority of scenes should meet the following quantitative specifications:

Prints should be timed so that the face densities of normal middle-gray points of interest are a density of 0.75 ± 0.15. The minimum density of any area required to reproduce detail should be 0.40 or above. The maximum black of any area where detail is required should be 2.0 or below.

Prints should be timed so that the scene-to-scene balance of over-all density is as uniform as possible.

Prints should be free from any spots, streaks, or scratches not present in the negative.

Prints should be surface-treated with a lubricant or other protective treatment to ensure smooth projection and to minimize wear and scratches.

The conditions listed above apply with equal validity to prints made in 16 mm either by reduction printing or by contact printing from original or duplicate negatives.

Sound Negatives. These should be processed to negative gammas and densities to give minimum intermodulation distortion results on variable density and maximum cancellation on variable area when printed to the proper contrast for the picture in the television print. With 16-mm printing, variable-area sound negatives are recommended because of their inherent 5- to 6-db advantage in signal-to-noise ratio. Either 16- or 35/32-mm-width film negatives are acceptable for 16-mm sound printing.

Leaders. Leaders should be SMPTE television leaders with either a print of the sound negative or black-printed in the sound area starting at least 20 frames ahead of

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[2] *Gammas as Measured by the Print-through Method.* This value of gamma has been specified because it takes into account variations in printing due to differences in color temperature and specularity of the printing light and difference in intensity level and the linear speed of printers. This is important because the effects of these factors are not the same for various types of print films.

The print-through gamma may be defined as that gamma value measured when the density of a gray scale is plotted on a horizontal axis, with the densities of the print from the gray scale being plotted on the vertical axis.

the first frame of picture in 35 mm and 26 frames ahead of the first frame of picture in 16 mm.

Color

Photography and Lighting for Optimum Quality from Color Film. Since there is no provision for contrast control in color-film negatives or prints available for use, more of the burden of producing acceptable color prints for TV falls on the photography and lighting. The lighting contrast should be kept to a level of 1.5 to 1 or 2 to 1, and unlit dark areas should be avoided. The exposure of the negative must be very carefully controlled in order to achieve maximum color saturation.

Most of the practices recommended for black-and-white photography are equally applicable here.

Negatives. Negatives should be processed as soon as possible after exposure. Developing should be done in accordance with the manufacturer's specifications.

Color Master Positives and/or Separation Master Positives. These should be exposed sufficiently to ensure a linear gray scale. Separation positives should be developed to the control gammas that will produce a balanced color internegative. Color master positives should be processed in accordauce with the manufacturer's specifications.

Color Dupe Negatives and Internegatives. These should be made on the proper film stock for reproduction from Kodachrome, separation master positives, or color master positives. Exposure should be sufficient to ensure a good gray scale and give optimum color saturation. Developing should be done in accordance with the manufacturer's specifications.

Prints. Prints should be timed so that they are dark enough to give good color saturation but not dark enough to make shadows too dense. The equivalent gray density values should be about the same as those given for the best results in black and white.

A & B Printing. This is recommended for the making of dissolves and fades, in the manufacture of prints for TV from original negatives, or for the making of color master positives. This practice avoids the use of second-generation material intercut with the original material, which causes desaturation and mismatch of colors.

Black-and-white Prints. Black-and-white prints from color negatives should be made by first making a panchromatic master positive from the color negative, in accordance with the gamma and densities as set forth for a normal black-and-white master positive. A dupe negative is then made as with a normal master positive. The black-and-white prints are made from this dupe to television specifications as outlined previously.

All the other practices as outlined for black-and-white laboratory procedures apply also in color, 35 and 16 mm.

Fire Prevention[3]

Following an extended investigation, acetate-base film in the form of ribbon for motion pictures was listed by Underwriters' Laboratories, Inc., as slow burning, the fire hazard being classed as somewhat less than that of common newsprint paper in the same form and quantity. Motion-picture safety film having a cellulose acetate base is now being marketed for commercial and general use. It is claimed that this film has a greater projection life and is otherwise superior as compared with the older type of cellulose acetate film.

This type of film can be identified by the words "Safety Film" printed at frequent intervals along the edge. In case of doubt, acetate film can be distinguished from nitrate by a burning test, using only a small piece of film and burning it in a room where there is no film and no fire hazard. Nitrate film will burn fiercely; acetate film will burn quietly.

The ignition temperature of cellulose acetate is between 700 and 800°F, as compared with about 300°F, for cellulose nitrate. A temperature of about 500°F is re-

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[3] Bulletin 283, National Board of Fire Underwriters, New York.

quired to produce the decomposition of cellulose acetate film. In the neighborhood of this temperature the evolution of fumes in material quantity occurs. These fumes are irritating and suffocating but not considered to be toxic under most conditions.

The decomposition of cellulose acetate film once started does not continue except under conditions where there is an external source of heat. On the contrary, in the case of cellulose nitrate film the decomposition continues when once started, even in the absence of external source of heat. This difference of decomposition is, therefore, of great importance from the fire and life hazard standpoint. Furthermore, great volumes of explosive and toxic gases are given off from decomposition of nitrate film, especially in a restricted supply of air, thus contributing to the life and fire hazard.

The rate of combustion of cellulose acetate film is relatively slow, and the amount of heat evolved is of a low order, being much less than that of paper or wood.

The most important safety factor with reference to cellulose acetate film is in its slow combustion, and any fire can be easily extinguished by the application of water or smothering, much in the same manner as fires in ordinary combustible materials.

The time will no doubt come when nearly all pictures will be on safety film, but there may be nitrate films in circulation for some time, and because of this, every precaution should be taken to avoid any relaxation in the regulations prescribed and methods imposed for the safe handling of flammable nitrate films. The safety factor supplied by the new acetate film can be taken advantage of by arranging its storage apart from any nitrate films. By this segregation, loss possibilities will definitely be reduced, and as nitrate inventories are progressively diminished, their isolated confinement will tend to control hazard possibilities further. In existing film exchanges, this segregation can be readily controlled by having separate film vaults for safety and nitrate films and marking their doors with the words "Safety Film" in *green* or "Nitrate Film" in *red*. Similar isolation of safety films from nitrate films can also be practiced using specially identified rooms for the safety film with such measures for protection against loss as may be desired. Small amounts of safety film can be appropriately stored in ordinary steel filing cases, but if the films are of high value, specially protected cabinets of the type designed for film storage should be given consideration.

In order to ensure the degree of safety now provided by the new film, it is suggested that all safety films be unmistakably identified by reel bands bearing in prominent letters the words, SAFETY FILM printed in bright green. All record cards and other control items that pertain to these films should also be printed in the same green color and bear as their main feature the words SAFETY FILM. In contrast, all flammable nitrate films should be equipped with reel bands printed in bright red with the words NITRATE FILM, with their record items correspondingly identified.

Film-handling personnel working under this plan for segregating the two types of film should take special care to prevent intermixture of the two types, and there should be exacting supervision of storage facilities to minimize all possible loss. By positive and intelligent management the safety factor provided by this new film base can immediately benefit all engaged in motion-picture-film activities. If such a plan for careful segregation is not followed, any place where both types of film are handled should follow for all film the safety precautions prescribed for nitrate film.

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Part 7

AUDIO AND VIDEO SPECIAL EFFECTS

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VISUAL EFFECTS

Electronic Switching Special Effects

In television video practice, the term "special effects," by accepted usage, is applied to techniques for creating visual effects which are beyond the capabilities of the normal complement of facilities found in the standard minimal studio. The purpose of such effects may be purely artistic or may be simply to aid the objective presentation of information. Electronic special effects can also be of economic advantage when they permit realistic simulation of pictorial material that would otherwise be prohibitively expensive.

The major category of electronic special effects is the use of electronic switching for simultaneous display of portions of two or more video signals by a pattern division of the raster. Other types of visual special effects are largely techniques for introducing distortions of the picture image, by either optical or electronic means.

Electronic Switching Techniques

Since the television picture is transmitted by a time-sequence scanning method, it is evident that appropriately timed instantaneous switching between two video signals can produce the visual effect of a geometric division of the raster area so that portions of each picture are displayed. Conventional electronic switching techniques readily permit the rate of switch required (on the order of 0.2 μsec). Methods of using this technique are categorized by the source of the signal which determines the pattern of the display. In the most elementary application, the "wipe" keying waveforms are generated by pulse circuit techniques to create geometric patterns. It is also possible to obtain keying waveforms of any desired pattern by processing video signals from conventional camera equipment. The simplest form of this technique uses an independent camera trained on silhouette art work of the desired pattern, so that the resulting video signal closely resembles a pulse keying waveform and requires a minimum of processing. The most advanced application is "matting" (also called "montage"), where the keying signal is derived from one of the two video signals to be combined. This permits placing a subject visually into any background scene desired.

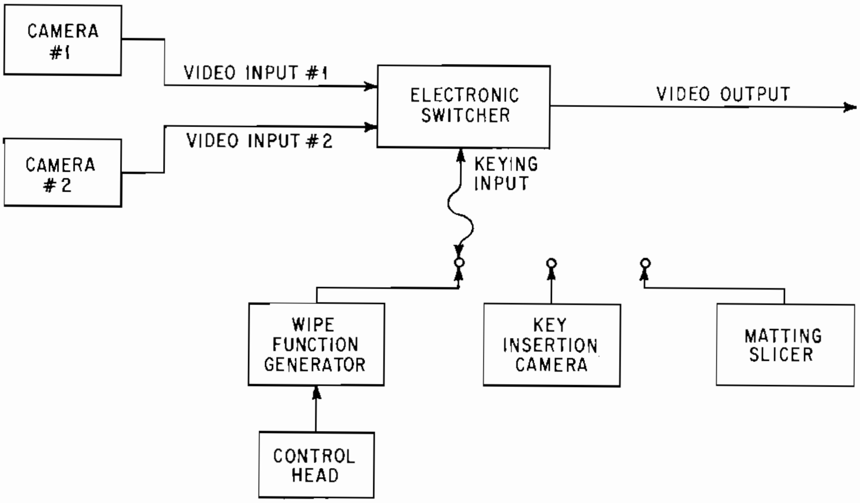

Fig. 7-1. Electronic switching special-effect system.

The arrangement of equipment components for these three forms of electronic switching effects is shown diagramatically in Fig. 7-1.

Electronic Switching

The circuit which is fundamental to any special-effects switching system is the electronic switching circuit itself. Functionally, this circuit takes three input signals, the two video signals and the keying pattern signal, and produces an output video signal which combines the two video signals in accordance with the area division established by the keying pattern signal. The keying pattern signal is assumed to be a two-valued function, or pulse signal. Switching circuits usually, however, include a clipper in the key-signal input channel to remove any noise or shading components that may be present. This permits the use of camera-generated signals developed from a silhouette art work without further prior processing.

The usual circuit arrangement (Fig. 7-2) employs a pair of gate tubes, such as the 6AS6, as the switching element. The keying signal, after clipping, is phase split so that it can be applied in opposite polarity to each of the two gate tubes. The gate-tube outputs are paralleled and fed to the output amplifier. Stability considerations usually require somewhat extensive auxiliary circuitry for clamping and blanking purposes. A chronic problem exists in the timing and shape of the opposed-polarity keying pulses, which should be precisely symmetrical to avoid a gap or overlap at the instant of switch. More advanced and complex circuitry has been applied to the solution of this problem, particularly for the matting application.

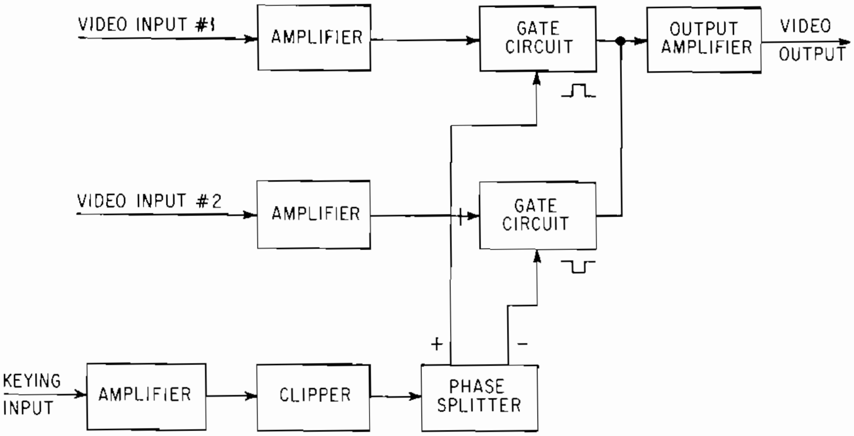

FIG. 7-2. Electronic switcher—typical circuit plan.

Wipe Function Generation

A wide variety of keying patterns can be electronically generated by conventional pulse circuit technique. Such signals are applied in two general ways (1) for a transition from one picture to another and (2) for a steady display of portions of two (or more) pictures.

The term "wipe," which originated as the description for the most elementary form of geometric transition (in which a dividing barrier sweeps across the raster with the new picture appearing behind it as it progresses), is commonly applied as a generic term to any system for electronically generating patterns of raster division. A "split-screen" is, of course, a stationary wipe. Some wipe effects actually involve more complex forms of motion, such as an iris action.

For the transition application, a variety of patterns are commonly employed, the simplest being the horizontal (Fig. 7-5) or vertical wipe. Diagonal wipes (Fig. 7-7) are also common. More complex wipes are possible with wedge and irregular shapes.

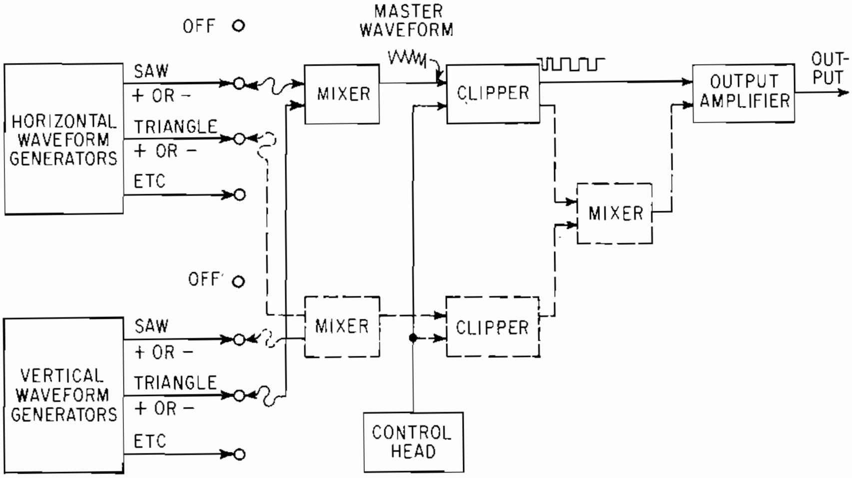

FIG. 7-3. Wipe function generator—typical circuit plan.

The box (Fig. 7-8) and the diamond are the most common shapes for the iris type of motion. A wide variety of more complex patterns can be electronically generated, including "venetian blind," "checkerboard," circular, star, triangle, etc.

Of the static patterns which are employed to display portions of two or more pictures simultaneously, the horizontal split screen (Fig. 7-5) is the simplest and is frequently used. Another popular pattern is the wedge (Fig. 7-6), in which a rectangular segment in one corner of the picture is keyed off, usually for insertion of the face of a commentator. A vertical split screen is sometimes employed to insert written material in a strip at the bottom or top of the picture. On occasion, for planned news coverage, more than two signals have been combined, and as many as five pictures have been combined to display simultaneously the faces of news commentators from widely scattered locations. When pictures are so combined from different locations, it is, of course, necessary to phase-lock the sync generator at the combining location. When pictures from more than two points are combined, a chain hookup is needed so that each successive point can phase-lock its sync generator and insert its contribution to the final combination.

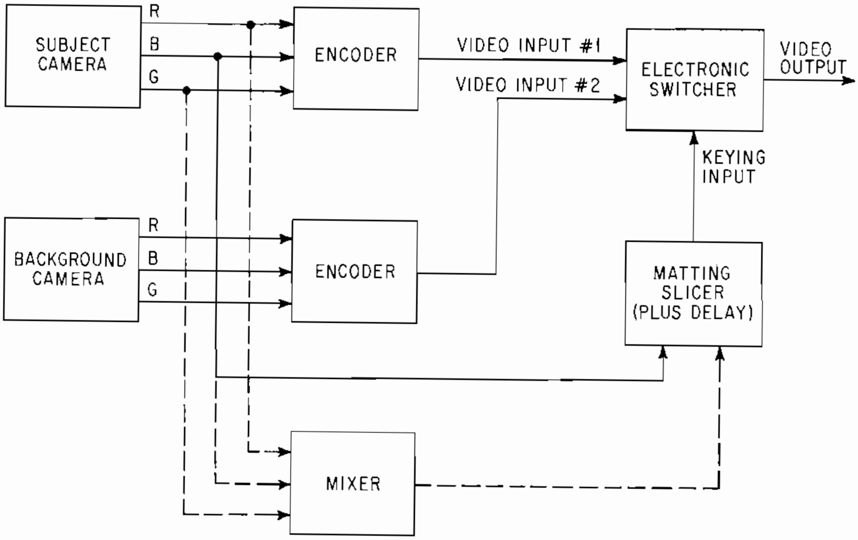

FIG. 7-4. Color matting system—block diagram.

Circuitry for the generation of wipe keying signals usually employs certain principles that are common to all practical designs. A typical block diagram is shown in Fig. 7-3. In the typical system, vertical and horizontal waveforms are generated as elements for the synthesis of keying signals. The simplest patterns use horizontal and vertical sawtooth and triangle. For more complex patterns, multiple frequency and parabolic waveforms can be used as well. The wipe pattern is generated from a master waveform, which may be a combination of basic horizontal and vertical waveforms, by double clipping (or "slicing") to develop a pulse signal whose timing will depend upon the clipping level. The motion is thus imparted to the pattern for transition effects by manually changing the clipping level through the amplitude range of the entire master waveform. Some patterns require independent clipping of two waveforms with following mixing and clipping (in effect, logical mixing) of the two resultant pulse signals. Additional combinations of mixing circuits and basic signals make possible an extremely wide variety of patterns. In elaborate systems, the major design problem becomes the switching arrangement for selection of a large number of circuit combinations.

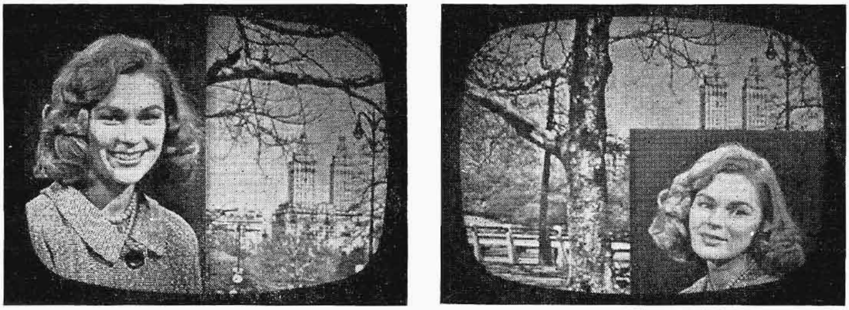

FIG. 7-5. Horizontal wipe or split screen.

FIG. 7-6. Wedge insert.

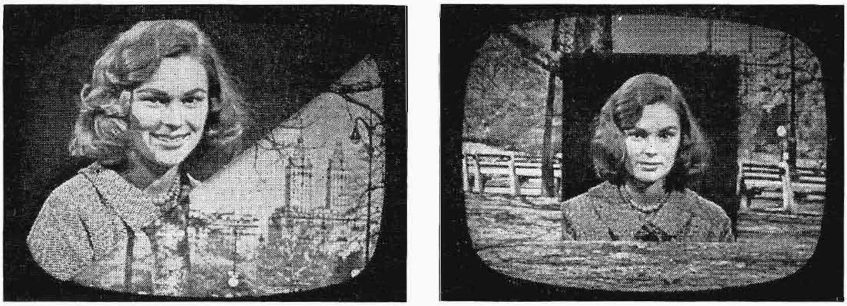

FIG. 7-7. Diagonal wipe.

FIG. 7-8. Box wipe.

FIGS. 7-5 to 7-8. Wipe and split-screen effects.

Keyed Insertion

Where an irregularly shaped pattern that cannot readily be generated electronically is desired as a split-screen or wipe pattern, it is necessary that the keying signal be produced by an image-scanning process. Conventional camera equipment can be used for this, either live or film. Flying-spot scanner equipment is particularly applicable to this application but has yet to be applied on a commercial scale.

The major application of keyed insertion has been for trick "split-screen" effects. There has been limited use for transitions, generally using a live camera with a zoom-type lens to produce the pattern motion. Film animation is another possible source for moving patterns, but its cost has seldom been considered justified.

Fixed keyed-insertion patterns are usually derived from live cameras with silhouette art work or with film cameras using projected slide or opaque material. In using a live camera with the usual type 5820 image orthicon, an important operating consideration is the lens exposure setting, since excess light produces electronic halation which can readily negate the usefulness of the camera chain output video signal for keying purposes.

Any camera signal requires double clipping to eliminate noise and shading components before use as a keying signal. The switching circuit will normally include sufficient clipping, but in some systems the key-insertion signal is fed through a portion of a wipe signal generator circuit to process it adequately.

The component pictures and results of a key insertion process are shown in Figs. 7-9 to 7-12. Figure 7-9 is the background camera, showing a map of the United States. Figure 7-10 is the key-insertion camera, a silhouette outline of the state of Missouri. Figure 7-11 shows the picture from the subject camera. In the final product, the girl appears within the state outline in Fig. 7-12.

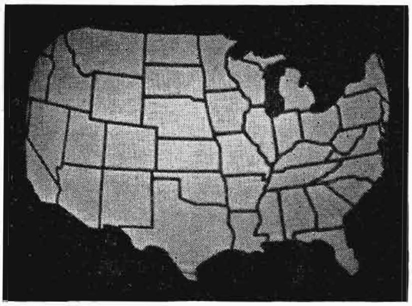

FIG. 7-9. Background camera picture.

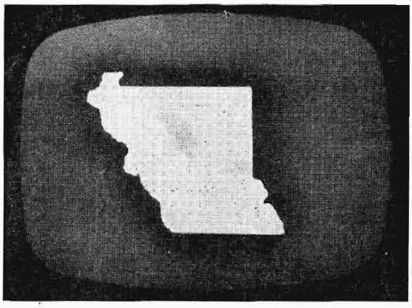

FIG. 7-10. Key-insertion camera picture.

FIG. 7-11. Subject camera picture.

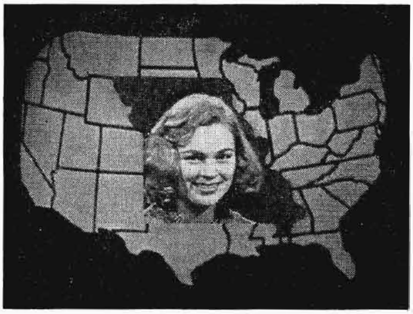

FIG. 7-12. Final key inserted picture.

FIGS. 7-9 to 7-12. The key-insertion process.

Matting

The object of the matting process is to insert a subject (usually human) into a background scene, sometimes for a trick effect but usually for the purpose of creating the illusion that the subject is actually in the scene. When skillfully applied, this process can offer an advantage of economically creating effects that would otherwise be prohibitively expensive.

To achieve matting, the subject is televised by a live camera against a flat backdrop of either black or white. If the video signal produced by the subject is completely differentiated in level from the backdrop, the camera signal can be properly clipped to produce the keying signal needed for matting. That is, if a black backdrop is used, all parts of the subject must be lighter than the backdrop; with a white backdrop, the subject must be entirely darker. The keying signal derived from clipping the subject signal is supplied to an electronic switch circuit, along with the subject signal itself and the desired background signal. This process places a more stringent demand on the electronic switching circuitry as regards the time of switch than does the wipe application, since a noticeable gap or overlap between subject and background is an artificial effect tending to destroy the desired illusion of continuity. Delay compensation usually enters into the system, since the keying signal "punches a hole" into the background into which the subject must fit with precision and will do so only if time concurrence is achieved between the two signal paths.

In actual practice, the achievement of successful matting faces such obstacles that great care must be exercised in its use, and as a result, it has not become a widespread or popular practice. The operating characteristics of the image orthicon are such that small dark areas of most subjects, even though not actually of less surface brightness than the backdrop, produce video signal voltages below that of any black background level that can be maintained. The white-background method has a tendency to distort the image of the subject by halation around its edges and also presents a lighting problem in the elimination of shadows on the backdrop. When the background must include the floor, the maintenance of a satisfactory reflectance on a surface that is walked upon is always a problem. The lighting must, in any case, always be set up with extreme care. When the setup is not sufficiently optimized, there is always danger of the appearance of "bleeding" resulting in the background scene appearing through an apparent hole in the subject—often an embarrassing mishap when it occurs. These factors have combined to make matting a highly specialized procedure, used only when the expense of a careful setup warrants it or for tricks or "gag" effects where mishaps can be tolerated.

Color Matting

Although it may appear paradoxical, matting can be achieved with greater facility in a color-television system than it can with monochrome. In the monochrome system, the signal-level separation between the subject and backdrop must be obtained from brightness, or luminance, information only. With color, an additional dimension of separation becomes available—chrominance. The result is that successful matting can be accomplished in a color system under much less stringent conditions than are required for monochrome. The usual practice is to use a backdrop of a bright primary color, sufficient to produce full "white" level in the corresponding channel of the system. The primary to be used is selected on the criterion that it be complementary to the predominant color of the subject. Since human subjects are most often used, blue is usually the optimum backdrop color. With mixing techniques, colors other than primaries, such as cyan, can also be used. An essential precaution is to avoid any use of colors approximating the backdrop color in the costume of the subject.

The matting-system layout in color differs from monochrome only in keying-signal source and processing, as shown in Fig. 7-4. The two video inputs to the electronic switcher are the encoded signals of the subject and background pictures. Instead of the subject signal itself as an input to the slicer, however, the desired primary component, before encoding, is used. This may be either an actual primary, such as the blue signal, or a matrixed combination.

Electronic-camera Distortions

Certain special effects for dramatic or trick purposes can be created by means of simple modifications to camera equipment or by the use of unorthodox operating techniques. The following are the most common and easily accomplished:

Scanning Reversal

Horizontal and vertical scanning are easily reversible by the installation of DPDT toggles switches directly in the yoke circuit. The effects made possible are the geometric inversion of the picture and horizontal reversing, which can be used for superimposition of mirror images.

Scanning Size Change

It is possible to produce sudden changes in picture size by a switch which changes scanning amplitude.

Polarity Reversal

Negative pictures can be produced by inverting the video signal, usually accomplished at the output of the camera video preamplifier. The simplest circuit technique is to change the output amplifier from plate-coupled to a cathode follower, or vice versa.

Ripple

The superimposition of an audio-frequency component on the camera horizontal scanning current causes a rippling motion in the picture which can be used dramatically to suggest dreams, fading of consciousness, etc. A frequency close to 60 cps or its harmonics produces a suitable motion effect. The audio signal is normally injected onto the grid of the horizontal scanning output tube. The effect is illustrated in Figs. 7-13 and 7-14 showing normal and rippled pictures, respectively.

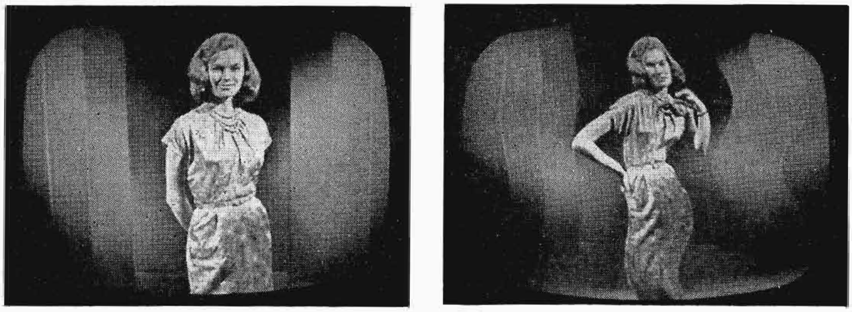

Fig. 7-13. Normal picture. Fig. 7-14. Rippled picture.

Figs. 7-13 to 7-14. The ripple effect.

Unorthodox Operating Techniques

An easily produced picture distortion with an image orthicon is obtained by reducing beam current below the value necessary to discharge highlights. The effect is to wash out all highlights in the picture in a manner that can appear quite weird for a "dream" or "bleary-eyed" effect.

Video operators can use their ingenuity in a variety of ways to produce odd effects that a director may desire. Another example is the reduction of target voltage on an image orthicon, changing the gray scale so as to suggest a night scene. Deliberate display of the dynode structure by low exposure and high beam current is another possibility.

Optical Effects

Many very interesting effects can be achieved by attaching various optical devices to the camera. Images can be multiplied, rotated, inverted, flared, distorted, and arranged in a variety of different patterns. Among the devices used to perform these effects are several types of prisms, kaleidoscopes, filters, and etched lenses.

Multifaceted Prisms

One group of prisms is referred to as the "multifaceted" prisms because of the multiplicity of plane surfaces on the face of the optical element. These prisms are placed between the subject and camera lens and produce one subject image for each plane surface on the face of the element and in a pattern corresponding to the arrangement of the surfaces. A diagram of a simple prism which produces three images is shown in Fig. 7-15. The center section *C* of this optical unit consists of an optical flat and passes reflected light rays from the subject S without deviation to the camera objective lens, which focuses it in the normal manner on the focal plan at *C′*. Rays from the subject S are bent by the wedge section at *A* at such an angle as to be received by the camera lens and focused on the focal plane at *A′*. In a similar manner, the subject is redirected by the wedge section at *B* to focus a third image on the focal plane at *B′*. Figure 7-16 shows a picture taken with a little more complex prism of this type with five wedges instead of two surrounding the central facet.

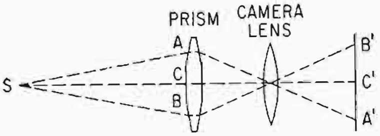

FIG. 7-15. Three-faceted prism.

FIG. 7-16. Multifaceted prism.

Dove Prism

Another useful prism is the Dove prism. This prism is placed in front of the camera objective lens in such a manner that its longitudinal axis coincides with the optical axis of the objective lens. Then rotating the Dove prism around its longitudinal axis will cause the image in the focal plane to rotate. Figure 7-17 shows this rotation in progress. It is interesting to note that for every degree that the Dove prism is rotated, the picture image rotates 2°. In this manner, turning the Dove prism through 90° will cause an upright picture to rotate through 180° and become upside down. Another 90° rotation of the Dove will complete the 360° rotation of the image and bring it back to its original upright position.

FIG. 7-17. Dove prism.

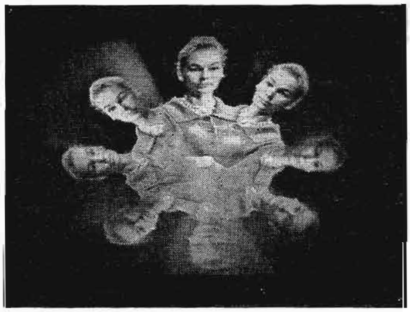

FIG. 7-18. Kaleidoscope.

Kaleidoscope

One of the oldest optical effect devices is the kaleidoscope. By utilizing the basic arrangement of the two mirrors which form a V and shooting through it, studio scenes and performers can be picked up in all kinds of kaleidoscopic patterns. The number of images produced will depend upon the angle formed by the two mirrors and can be determined by dividing 360° by the angle. For example, if the angle is 60°, six images will be formed. Figure 7-18 shows a picture taken with a kaleidoscope whose mirrors formed a 45° angle. While smaller angles will produce more images, it should be noted that there will be a greater difference between the sharpness and contrast of the unreflected image at the top and the last generation of rereflected images or image at the bottom. Even though front-surfaced mirrors were employed in the kaleidoscope with which the illustration was taken, there is a marked difference between the top and bottom images.

Filters

Color and polarizing filters are also useful in the production of effects. In black-and-white television, radical changes in the gray scale of costumes, graphic arts, scenic elements, and make-up can be created by the use of color filters. The lines in the face of the girl shown in Fig. 7-19 were applied with a red make-up pencil and a "blue" filter on the camera which took the picture made them appear very bold. Without any change in make-up, the blue filter was replaced with a "red" filter with the result as shown in Fig. 7-20. By adding one filter as the other is removed, in one continuous operation, actors can be made to appear to age or otherwise become transformed right on camera.

FIG. 7-19. Blue filter.

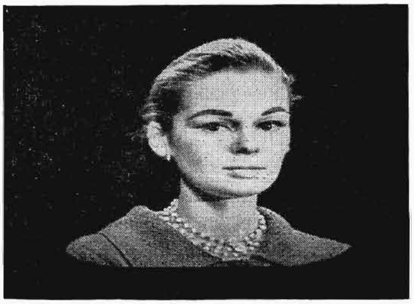

FIG. 7-20. Red filter.

In color television, the filters quite obviously change hue and can be used only when there is some particular advantage in disturbing the color balance.

Polarizing filters also produce effects when used in conjunction with polarized light. Since most studio light is not polarized and much of what is, is of random polarity, it is usually necessary to employ polarizing filters on light sources to produce the effect. For example, two words on a sign might be lighted with polarized light of different polarities, one horizontally polarized and the other vertically polarized. Rotating a polarizing filter on the camera would then produce the effect of the words fading in and out alternately.

Etched Lenses

Another type of effect can be produced with etched lenses and fine-meshed screens. Ordinarily, great care is taken to avoid scratches on lenses, but in this particular case, lenses or optical flats are etched on purpose with some pattern such as a series of concentric circles, dots, or crosshatching. The etching is fine enough not to cause much interference with picture quality except to deflect highlights in such a manner as to produce odd patterns of light flare. The picture shown in Fig. 7-21 illustrates the effect and was taken with a Hartley lens attachment.

Projected Backgrounds

For many years, scenic slides have been projected on the stage and in motion pictures to provide scenic backgrounds. The technique has been adopted by television and is commonly used to make fast background changes, provide backgrounds where photographic realism and authenticity are essential, and produce graphic or pictorial illustrations on news and special-events types of shows as well as commercials. In this latter group, the purpose is to "tie in" narrator and picture illustrations in one camera shot to permit the narrator to point to graphics or scenic features and provide a transitional shot between narrator and picture illustrations.

Rear and Front Projection

Although projected backgrounds are mostly rear projected, they are to a lesser extent projected from the front. When they are front projected, the projector is placed overhead and directed down on the front of the background screen at a steep angle. While this eliminates the need for space behind a screen, it results in some loss of playing area immediately in front of the screen where the actors cannot play without interfering with the beam of projection as illustrated in Fig. 7-22. In addition, some "keystoning" will result from the axis of projection forming less than a 90° angle with the plane of the screen, and this may require a compensating predistortion of slides or provision for an optical correction.

Fig. 7-21. Hartley lens.

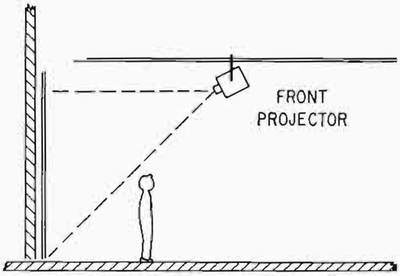

Fig. 7-22. Front projection setup.

While rear projection must of necessity be used with translucent screens, front projection can and customarily is used with opaque screens. Because of the superior diffusive characteristics of opaque screens, the "hot-spot" problem normally associated with rear projection, in which the center is bright or the side toward the camera is off axis, is not experienced with front projection. Cameras can dolly from one side to the other without apparent change in the light distribution of the projected picture.

Projection Lenses

To present the camera with the most uniform distribution of screen illumination in the case of rear projection and the least amount of keystoning with front projection requires the use of projection lenses of long focal length. Unfortunately, these lenses create the longest paths of projection, and this consumes much space behind the screen in the case of rear projection and much playing area in front of the screen with front projection. However desirable it may be to produce this technical quality, the long lenses seldom can be used in live television studios because of the ever-present problem of space. Fortunately, because of the operating characteristics of the camera picture tube (with highlights leveling off above the knee of the characteristic curve), unevenness of light from lenses of short focal length is not so much of a problem in television as in motion pictures and the quality is generally acceptable.

Light Sources

Both incandescent lamps and carbon arcs are used as sources of projection light, with the former preferred and most commonly used because of operating simplicity. Except for miniature screen applications, the minimum useful lamp for black-and-white television is the 2 kw. For color, requiring about three times as much light, the 2 kw is of little value and even the 5 kw has very limited usefulness.

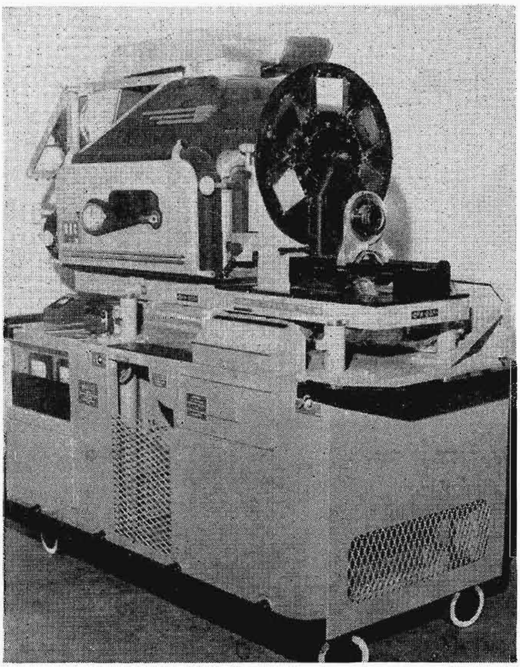

FIG. 7-23. Arc slide projector. (*Courtesy of NBC.*)

For the very large black-and-white backgrounds, incandescent sources are inadequate and carbon arcs, such as the one shown in Fig. 7-23, must be used. As an example of the limits encountered, a fairly efficient projector employing a 5-kw lamp delivering 7,000 lumens on a 9- by 12-ft screen would produce approximately 70 ft-c on the projector side of the screen and, using a fairly typical translucent screen with good diffusion and a transmission factor of 50 per cent, about 35 ft-c on the front or opposite side. This latter measurement then represents the maximum illumination possible in the clear areas or brightest highlights in the slide. Assuming that the actors are lighted for black and white with a base lighting of 100 ft-c, faces with a reflectance of 35 per cent would be as bright as the brightest background-scene highlights. Considering that a 9- by 12-ft background is not large, the capabilities of incandescent projectors becomes apparent. In actual practice, though, studio lighting levels are lowered somewhat and lens aperatures opened so that screens of 200 sq ft or more can be used satisfactorily.

Slide Sizes

Of the slide projection equipment, some projectors use 4- by 5-in. slides and some use the 3¼- by 4-in. slides. There is little difference in the size of the slide and also the performance of the equipment. Generally, larger slides are easier to cool, but the difference here is too small to be very significant. Equipment employing slides smaller than 3¼ by 4 in. is generally intended for the visual aid field and, except for use with the miniature screens, has little application for background projection.

Film Projectors

Both 16- and 35-mm film projectors are used for moving backgrounds. A typical 35-mm projector in its housing and with its companion operating booth is shown in Fig. 7-24. Because of the inadequacy of incandescent film-projection lamps for anything other than very small screen applications, carbon arcs are used almost entirely. The amount of light which can be projected through a small 16-mm film frame without burning it is very limited. Something like 2,000 lumens is typical and satisfactory for small screen applications in black and white but of little value for color.

FIG. 7-24. 35-mm rear projector. (*Courtesy of CBS.*)

For color, arc sources are too blue and must be heavily filtered with something close to an Eastman Kodak 85-B Wratten filter, depending upon the color of the screen. If yellow flame carbons are used, less filtering is required and consequently less light is lost.

Some film moving-background projectors operate at standard sound speed, 24 frames per second, while others run at 30 frames per second. The 24-frame projectors use a two-three pull down, alternate frames being scanned for two and three fields, respectively, and commonly have a 37½ per cent application time. While more expensive, sound tracks can be used, and the running time of film will not be altered.

Projectors that run at the 30-frame rate are generally less expensive because a standard movement is used with only the gearing and/or motor speed changed. The application time is 50 per cent for 90° shutters and longer for smaller shutters. Sound tracks cannot be used at this speed, and picture material, if shot at the 24-frame speed, will move somewhat faster.

Screen Materials

The performance of rear projection depends to a considerable degree upon the quality of the screen used. One of the desirable characteristics of a good screen is high light transmittance. A screen which transmits a small percentage of light wastes projection light which, as pointed out previously, is commonly in short supply. In addition to transmittance, a screen material must have good diffusive properties. For example, light passes freely through chicken wire and window glass but no diffusion takes place and consequently no image is formed. Diffusion should go beyond just forming an image but should be as complete and uniform as possible. Poor diffusion results in a severe bright area, or "hot spot," surrounding the point at which a straight line between camera and projector passes through the screen. As the camera arcs to one side, the hot spot follows and the opposite side of the screen gets quite dark. Figure 7-25 shows curves resulting from measurements of three commonly used screen materials. With the light source behind and perpendicular to the material tested, brightness measurements were made on the opposite side. As indicated, readings were taken at angular intervals between the perpendicular and plane of the screen, and since the material exhibited symmetrical characteristics, only one curve is shown. While material *A* showed high transmittance but poor diffusion, material *B* shows a good diffusive characteristic but rather low transmittance. Although material *B* would present the camera with even brightness over the screen area, the waste of projection light would be uneconomical and limit the size of the picture which could be produced. On the other hand, material *C* shows both a good diffusive characteristic and good light transmittance. Of the three materials, *C* is definitely superior.

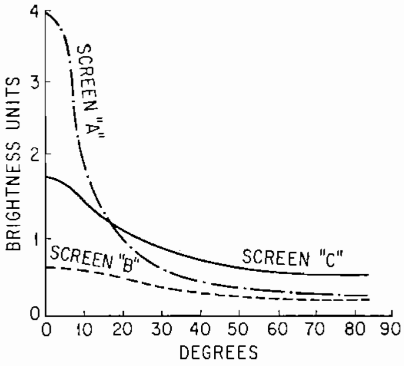

FIG. 7-25. Diffusion characteristics of screen materials.

Another consideration is the quality of reflectance. It is quite obvious that the reflectance must be diffuse, or nonspecular, to prevent the camera from picking up set lights, but in addition, it is desirable that the reflectance be kept low in order to maintain picture contrast. To reduce reflectance, it has been common practice in black and white to color-screen materials. While this reduces reflectance, it also reduces transmittance. Whether this is a good practice depends to a considerable extent upon the ultimate use. If the screen is used where spill light can be controlled, the problem of contrast has little significance and the undyed material with higher light transmittance is better. Where this control over spill light cannot be maintained, then the sacrifice of transmittance for lower reflectance may be a good one.

Beyond the optical requirements, the physical characteristics of the materials are of some consequence. It is customary to expect rear screens to be shifted around like studio scenery, and for this practice it is desirable that screens be made of lightweight, reasonably rugged materials. Some of the plastics, such as polyethylene and polyvinyl chloride, have been found suitable. Another excellent material is latex. While this latter material has excellent optical properties, it is somewhat more fragile than the plastics. Just how durable the material must be is something that can best be decided after the actual application is known.

Lighting for Rear Projection

In addition to good equipment, the proper employment of studio lights is also essential to the successful use of rear projection. It is important that "key light" be kept off the screen. To do this it is necessary for the actor to play a distance at least equal to his height in front of the screen just as he would—or should—with other background scenery. Then it may be necessary to direct the key lights in from the side and employ them as cross lights as in Figs. 7-26 and 7-27. The esthetics of this may be questioned, but the end result seems good enough to justify the means. "Back lights" as indicated in Fig. 7-26 should be barn-doored to keep spill off the screen. And finally, the placement of the "fill light" is important. Fill light should be placed on a line which in plan is an extension of the axis of projection right through the screen into the playing area and in elevation as in Fig. 7-28. With the fill light set up in this manner, the camera will see a bright area on the screen corresponding to maximum reflectance of this light. By a fortunate coincidence, this bright area corresponds rather closely to the projection hot spot. Since the fill light has the effect of reducing contrast and since it reduces it most in the hot-spot area where contrast is highest, the proper setting of this light will greatly minimize the hot-spot effect. While this fill-light setup is not offered as a panacea for the hot-spot problem, it is suggested as a means of minimizing it.

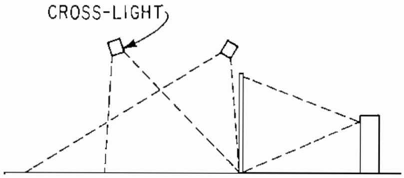

Fig. 7-26. Cross lights on rear projection set (elevation).

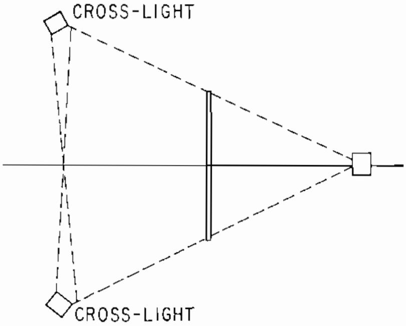

Fig. 7-27. Cross lights on rear projection set (plan).

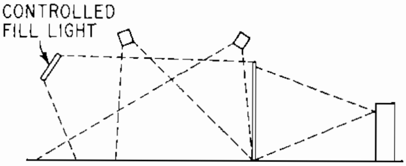

Fig. 7-28. Fill light on rear projection set.

Shooting Rear Projection

Good projection and screen equipment having been used and the set lighted properly, there still may be evidences of the hot spot which will prove troublesome unless the screen is shot properly. Referring to Fig. 7-29, the best way to shoot a scene from projector *A* is along the axis of projection with camera *A*. To camera *B*, the right side of the screen would appear bright and the left side dark. If it is known that the preponderance of shooting must be done with camera *B*, then projector *A* could be moved to the location of projector *B*. Focus would have to be split, and keystoning might have to be corrected. The same rule also applies to elevation. With the axis of projection parallel to the floor as shown in Fig. 7-30, the scene should be shot with camera *A* rather than camera *B* or *C*.

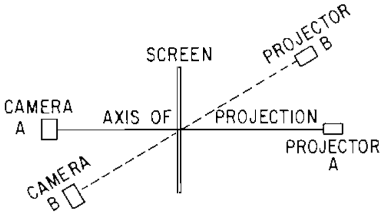

FIG. 7-29. Shooting on axis of projection (plan).

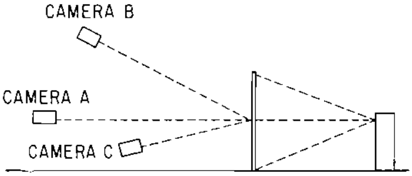

FIG. 7-30. Shooting on axis of projection (elevation).

Slide and Film Processing

Another essential element in background projection is the slide or film. To what gamma these should be processed will depend to some extent upon the nature of the picture and how used. Generally, density results in loss of projection light and should be no greater than is required to reproduce the necessary picture detail and contrast. Density beyond the contrast range of the screen or the television system is to be avoided. Safe rules to follow are those currently set forth for good television film reproduction.[1]

AUDIO EFFECTS

Introduction

Sound effects in television are similar to sound effects in radio, but there are definite differences. For instance, in radio where there is *no* picture, the sound effects must create an image in the listener's mind. Actually the effects must be very real, and there can be no doubt left in the listener's mind as to what is happening. If the sound is obscure, then the dialogue carries the story to make sure everything is obvious for the listener. So the sound effects here must be quite realistic.

In TV the eyes take over for most things and the ears are not so conscious of the sound effects except those which are easily recognized. The important problem here is that the sound effect must synchronize with the picture exactly. Otherwise the out-of-sync action will be noticed. In radio any slight delay could be covered by the actor, but in TV this is difficult to do. The sound effect in TV does not have to be so creative, depending upon what is seen. However, quite often an effect is more complex and requires more study. It depends entirely upon the scene. It is sometimes even possible, if a scene is fast moving, that the effects may be completely submerged and music takes over. Then, only the highlight effects take over.

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[1] K. B. Benson and J. R. Whittaker, Monochrome Television Film Standards, *J. SMPTE*, January, 1958.

There are four basic types of effects which must be considered for TV work.

First are the effects that are on mike or on camera. These effects one would expect to hear with a picture, as the picture would show the effect in action, for instance, a telephone bell ringing. The video picture would show the telephone bell or handset, and the audio would transmit the bell ringing—when the telephone is answered, the sound of the cradle being lifted would be heard. There are many other effects on mike or on camera which might have to be done by sound effects.

Second are the effects that are off camera. These effects are very much like radio effects and must be quite creative in themselves. They must paint a picture strictly by audio. For instance, perhaps a scene calls for the arrival of a person in a car. Let's assume that one of the actors might be looking out a window from inside a house. The viewer hears a car drive up—which is off camera, actually a sound effect. The actor would react to this effect, and the camera stays with this actor, never going outside. The car stops; the car door opens and closes; the car drives off. All this time the camera stays inside on the actor's face to get a reaction shot. The next things that are heard are footsteps and a knock on the door. So far everything that was heard was done by sound effects. When the actor opens the door, a second actor is standing in the doorway. The actor had been there all the time, but the audience got the story. It was all done with sound effects.

Third type of effects are those that are used for background or to set a scene. For instance, if a scene opens outdoors or on a street, one would expect to hear some traffic sounds—especially if it is a city street. It might be a side street, and a car might never drive past, yet as long as the camera is outside, the viewer would expect some sound. In a night scene outdoors in the country, night sounds like crickets would be heard. All these various effects help to set the scene.

The fourth type of sound effect in TV which is completely different from radio is the type where the sound man must create a sound track for a *silent* film. This is done mostly with news film, which is usually shot without track except for film which may have dialogue—and anything and everything may appear on film. It is up to the sound-effects man to get a viewing of this film and then put in these effects while the film is broadcast on the air, and this is one place where synchronization is very important. Usually there is never sufficient time to prerecord any sequence of effects before air time, so the sound-effects man needs equipment that is considerably flexible. In the following pages some of this equipment is described.

Sound-effects Console

Introduction

Radio and television production requires a wide variety of sound effects. Some of these effects are produced manually, some electrically and some from recordings of the actual sound. In order to reproduce and amplify these various effects, turntables, amplifiers, and associated equipment are necessary. A console (Fig. 7-31) to do just this for TV has been designed and constructed, and several have been in use for a number of years at CBS.

The Turntables

The console consists of three variable-speed turntables and four pickup arms. The variable speed is very desirable for sound-effects use. Most of the sound-effects records are cut at 78 rpm, but by being able to change record speed it is possible to get a variety of effects from the same disc. For instance, with a sound-effects record of a car running, the variable speed allows the sound-effects man to vary the speed during a chase scene or to even slow down and stop the car. Records played at 78 rpm can give other effects at slower speeds. For example, a waterfall record can be made to create an explosion at slow speeds.

FIG. 7-31. Sound-effects console. (*Courtesy of CBS.*)

The Pickups

The four pickups used are so designed and installed that any two arms will work on at least one table, so that all four arms can be used at once. This is valuable for cross fading and continuing the same effect for a long period of time such as a car running, a train-wheel click, etc. In addition, two different cuts of the same record can be played at the same time or quickly cross-faded. Another effect is to play a smaller record of one effect on top of a larger record, in effect, having a fourth turntable. Still another effect is to place two pickup arms in the same groove. By so doing an echo can be obtained, as one arm is one-quarter turn behind the other arm. The type of pickup used is a crystal with a replaceable steel needle. The reason for this is the necessity for fast cueing of sound effects. Originally a magnetic induction pickup was used, but the men were missing cues, so the crystal type was installed. It is not possible to play LP cuts with this type of arm. The fidelity is good enough for most sound-effects use with the exception of applause, which is difficult to reproduce authentically under any condition.

Amplifiers

Each pickup is equipped with its own preamplifier with a self-contained equalizer. The equalizer can raise or lower the treble end. This is useful for sound effects to be able to change response to suit arising conditions. It is possible with this setup to play voice cuts of records made overseas and make them more understandable than if they are played on so-called Hi-Fi reproducing equipment. These preamplifiers are fed to a mixing network along with two other inputs. The two other inputs can handle a microphone for acoustical or manual effects such as doors, telephones, bells, etc., or one of these other inputs can use an input coil instead of a preamplifier. Then it is possible to use additional high-level inputs such as other turntables, Foster electronic gun, tape devices, etc. The individual controls have a cueing position on the fader so that a cue can be found rapidly even though the console is feeding other effects on the air. This is very useful when last-minute changes have been made or a marked cue has been lost during an air show. As shown in the block diagram, Fig. 7-32, there is a booster amplifier between the mixing network and the master volume control.

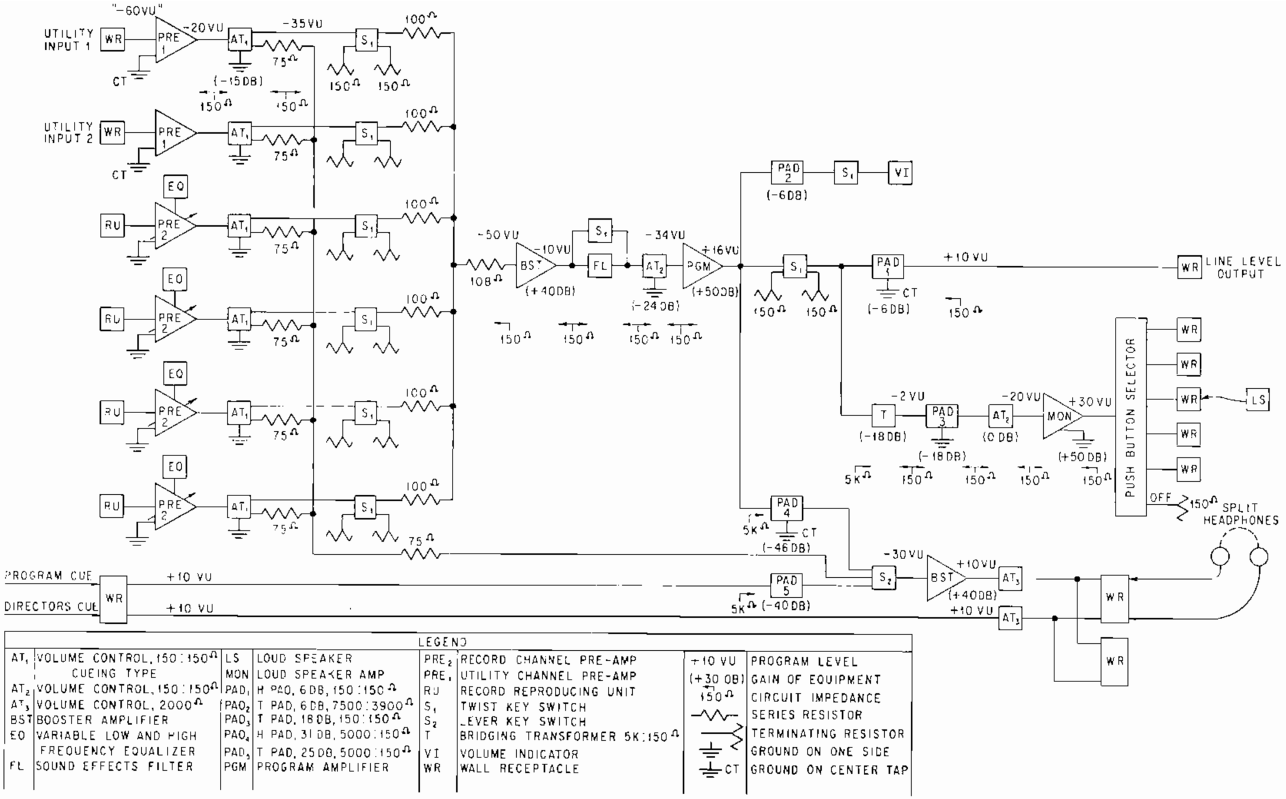

FIG. 7-32. Sound-effects console—block diagram.

Miscellaneous

A sound-effects filter of the low-pass–high-pass type is used for an over-all effect. This device has roll-off frequencies of off-100-250-500-1,000-2,000-3,000-4,000-5,000 on the high-pass and off-5,000-4,000-3,000-2,000-1,000-500-250-100 for low pass. Provision is made to feed a cue speaker for the actors over the particular set in which a scene is played. This is important so that the actors can hear the sound effect and react to it. It is possible to set up as many as six speakers in this way. An over-all volume control is used to prevent feedback between speakers and the sound-effects mike.

Conclusion

To show how a sound-effects man is actually set up to do a show using this turntable, see Fig. 7-33. First of all, the output of his console is fed on a line directly to the control-room audio console. He checks levels by using a tone record when he checks in. Usually his fader in the control room is left open, and he is responsible to see that only those sounds that go to the control room are the correct sounds. The line that feeds the control room carries all his effects–recorded, acoustical, or electronic. In order to work this equipment remotely from the studio, the sound-effects man needs first of all to wear earphones so that in one ear he hears program cues which includes his own effects. In the other ear he can select either director's cue or boom cue, as he must anticipate every cue. He has to be ready for it when it appears on the screen and synchronize with the visual effect. At this point he could use several heads, one to watch the monitor, one to watch the script so as to prepare the up-coming effects, one to watch the VU meter, one to watch what he is doing at the moment he is making a particular effect. He must ride all his own gain including his own mike and he able physically to fade on and off manual effects. He must

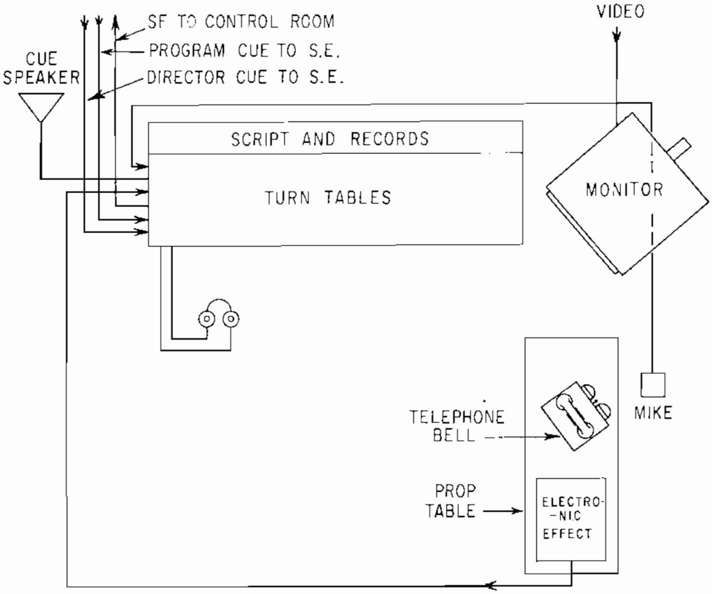

FIG. 7-33. Simplified circuit showing how a sound-effects console is connected to control room.

make sure the level to his speaker is enough so the actors can hear the effect but not so high as to cause feedback to his own mike.

Original work on sound-effects consoles was started many years ago by Walter Pierson and more recently by Davidson Vorhes. Acknowledgments are also made to Howard A. Chinn, CBS chief audio video engineer, under whose direction this design was undertaken, to Price Fish and Bob Monroe, project engineers on the turntable console.

Electronic Gun

The Problem

A device to reproduce the sound of gunfire electronically has been a desire of sound-effects men for many years. There is now such a device that comes very close to doing just that. To achieve the dynamic range of an actual gun, the acoustic range is impractical, so the next best approach is necessary. That approach would be a sudden change from zero sound to maximum in as short a time as possible. The first approach was to key in some sort of a continuous sound having the continuous sound set at a maximum level. The next problem was to fade out this sound at an appropriate rate so as to simulate a gun firing. In dramatic shows in radio, live guns have been used for some time and can create a good effect. One problem has been the acoustic problem of damage to the microphone. As previously mentioned, an electronic device is impractical to get the same level. It is impossible actually to read the volume unit of a live gun, and usually the audio man just lets it ride. The peak is so high and short it is usually ignored with the thought that nothing can be done about it anyway. In TV there is an additional problem. If an

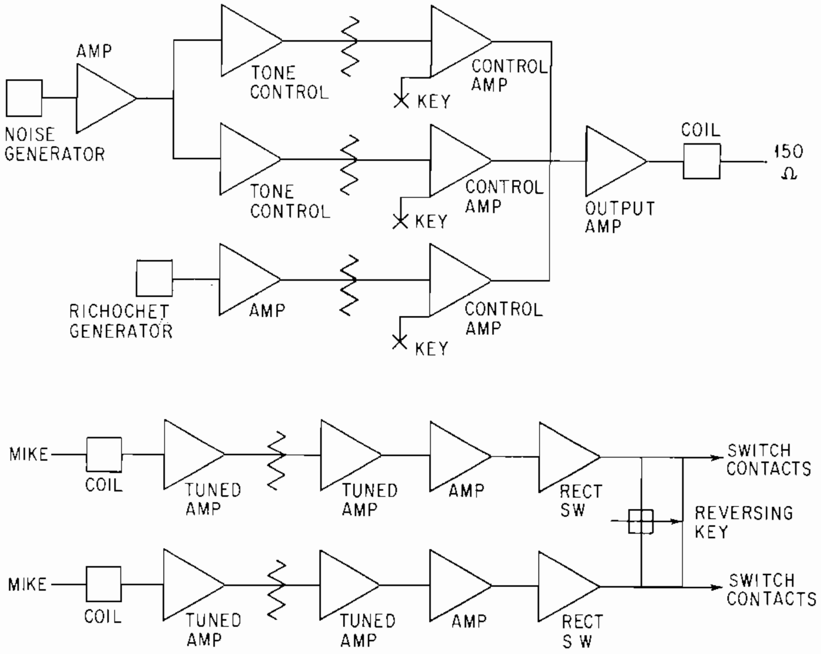

FIG. 7-34. Foster gun and Foster remote control—block diagram.

actor is handling a live gun on a set with an open boom mike, the gain of the circuit is so high that the audio man has very little if any control on the live gunshot, which will then reach the TV transmitter with enough level to actuate the limiter. As the limiter acts very rapidly, the louder the level reaching the limiter, the less sound that is actually transmitted because the limiter is pushing down as fast as the sound is pushing up. When the sound effect stops, the limiter requires a fraction of time to recover—sort of catches its breath—and, consequently, there is no sound at this point at all. So a gunshot that may sound great in the studios sounds terrible on the air, particularly at the local transmitter. Across a network it will not be too bad, as the various audio amplifiers will do a certain amount of compressing and prevent the rest of the transmitters from limiting along the network.

The Solution

Since the level of an electronic device *can* be controlled, the maximum is controlled which never reaches the level of a live gun. So to simulate a gun, the sound is extended instead of peaked. In other words, the gunshot is stretched out, which makes it sound big in the listeners' ears. This whole effect can be done simply with one tube acting as a noise generator and a second tube as a keyer. So to overcome this difficulty the electronic gun actually extends the length of the sound effect by adding to the original gunshot and putting a tail on it. The live gunshot can actually trigger the electronic gunshot but has to do so very rapidly; otherwise there is a double-shot effect. Another method is to not have any sound from the actor's gun, only smoke, and the sound-effects man fires the electronic gun manually. Here there is much more realism and levels are maintained. In TV it is best to work down from the loudest sound such as a gunshot to get a proper dynamic range between gun-

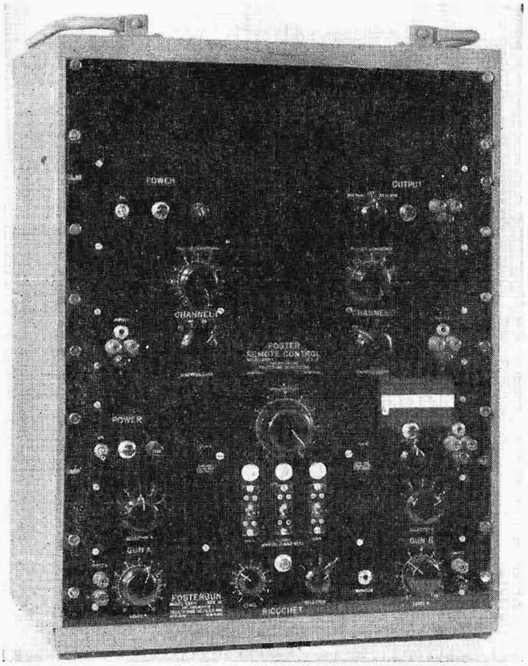

FIG. 7-35. Foster gun and Foster remote control. (*Courtesy of Teletronic Devices.*)

shots and dialogue. Usually there is considerable compression and equalization in film which is not done in live TV. Consequently, there is much better control in film, and the gunshots on film sound fine. Shown is a block diagram, Fig. 7-34, of a very elaborate electronic gun and Fig. 7-35 with two guns, double remote control, ricochet, etc.

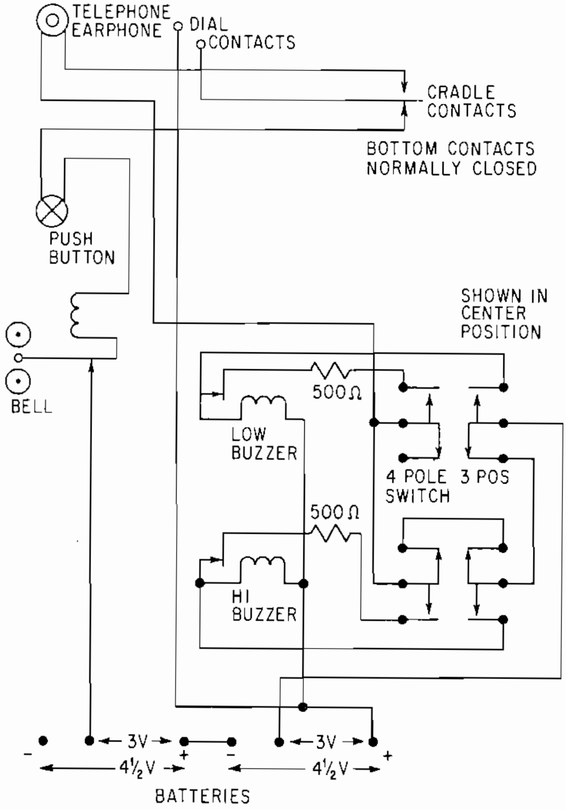

Fig. 7-36. Circuit of regular telephone with bell, dial tone, ringing effect, and self-contained batteries.

The Telephone

Telephones are widely used in TV dramas as well as in radio. In Figs. 7-36 and 7-37 we see a sound-effects telephone which has gained wide acceptance in the industry. This design accomplishes the following effects:

Telephone Bell Ringing. The bell sound that is used is a general type and can be used for a wide variety or types of telephones and will be acceptable. Operated by the sound-effects man this can also be rung on the set by remote control.

Telephone Ringing in the Line or at the Other End. Here there is no bell sound, but it is the sound the caller would hear in his earphone as the second party's telephone is being run by the telephone company. It is operated by the sound-effects man.

Various Types of Clicks. The clicks are used to indicate connecting parties together or a distant receiver being hung up. This sound would be heard by the caller who would be on camera. It is operated by the sound-effects man.

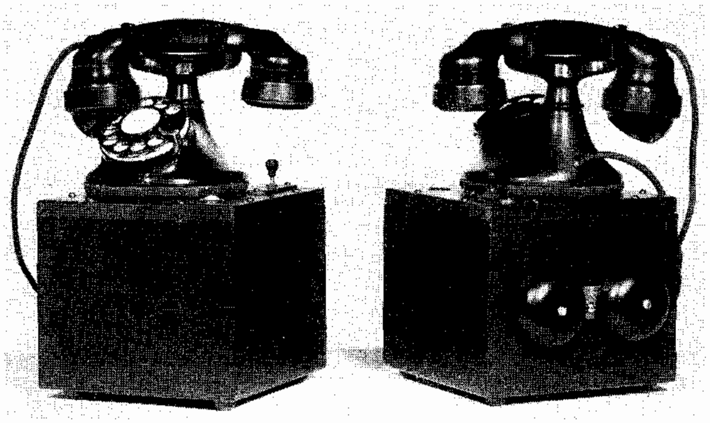

Fig. 7-37. Regular telephone with self-contained batteries, busy signal, dial tone, ringing effect and bell.

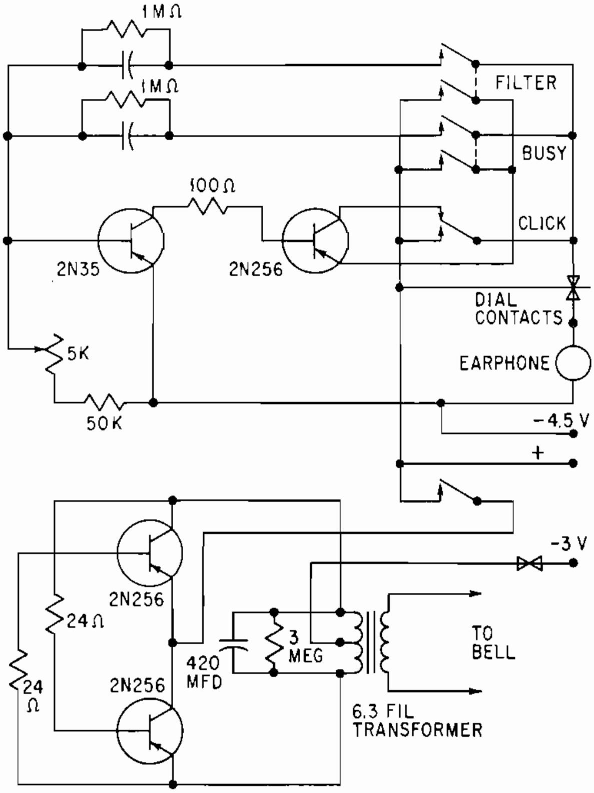

Fig. 7-38. Circuit of electronic telephone showing transistors.

Busy Signal as Heard by Caller. This is operated by the sound-effects man in any rhythm the director desires. Very close to the actual sound—good enough to give the effect.

Telephone Effects Using Transistors. In addition to the telephone device shown, CBS has recently developed in the sound-effects department a method of generating and amplifying the necessary effects for telephone use with transistors. Circuit data are given in Fig. 7-38 shown when a battery supplies the power for the two-tone generator circuits, key click, and bell-ringer effect (Fig. 7-39). This is all contained in a modern handset with the handset mounted on the batteries. This particular type of bell set sounds very modern, so it can really be used only with a modern telephone prop. All the above effects are performed on the sound-effects microphone, and it is up to the sound-effects man to achieve the right perspective according to the picture. This is done not only by a change in volume as the picture gets tighter on the telephone ringing but also by bringing the instrument closer to the sound-effect microphone. Other telephone effects are achieved in a variety of ways.

FIG. 7-39. Electronic telephone using transistors.

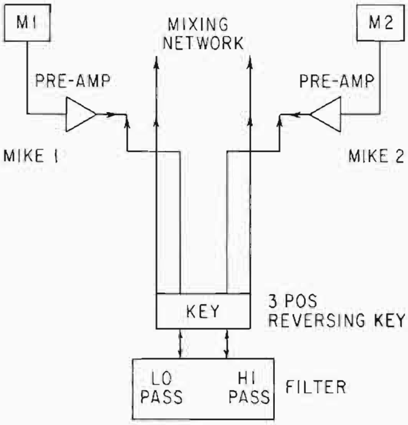

FIG. 7-40. Circuit showing hookup of two-way telephone filter effect.

Telephone Filter. For instance, a so-called telephone filter uses a normal microphone which is fed through a sound-effects filter. The sound-effects filter is usually a low-pass–high-pass type which in essence then becomes a bandpass filter. This means that the low frequencies and extreme high frequencies that can be heard normally are cut off with the sound-effects filter, so the effect is that a person is talking over a telephone or the voice is "filtered." Quite often in TV as well as radio the actors switch places or reverse their "on" and "off" camera positions in which case the filter mike has to be reversed also by the audio man. This can be done with one filter unit and a reversing key that requires the output of the two mikes that are being used to be reversed. The reversal takes place at the output of their respective preamplifiers (see Fig. 7-40). Another possible method is that the filter is switched by the switcher on certain camera takes. This is a video interconnecting system with the audio filter. This would actually be set up for each program as needed. This method helps eliminate errors.

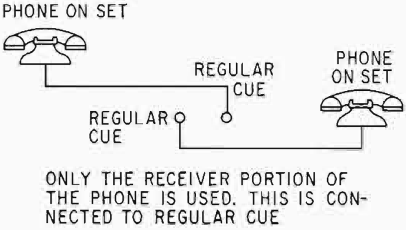

FIG. 7-41. Circuit showing hookup of practical telephones.

Practical Telephones. Another device that is needed in TV is a "practical" telephone for the actors talking on the telephone—both on and off camera. These telephones are made practical by actually (Fig. 7-41) connecting the receiver part of the telephone handset to a cable that can connect directly to program cue. So the actors then can hear themselves as well as all the program and the other end of their telephone conversation even though they may be quite a distance apart. Occasionally a switchboard can be used in a show which is not practical except for inserting the telephone plugs. In this case, the sound-effects man would have to supply all the necessary buzzers and bells that the switchboard sound might need. It usually is simpler to add the sound effects than it is to try to make the switchboard practical.

Bells, Buzzers, Chimes

A device that is widely used in TV is the sound of a doorbell or door buzzer and occasionally a chime. Once a particular bell or chime is selected for a set, this unit has to be always available whenever this particular set needs it. Door buzzers are made up in such a way that a selection of various ones is available (see Figs. 7-42 and 7-43). The buzzers and bells are mounted on wooden boxes which also contain the operating batteries. They are shock-mounted on rubber also. Several types of chimes, door chimes especially, are always in demand. Figure 7-44 shows one type.

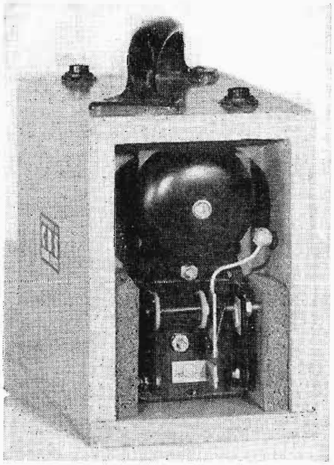

FIG. 7-42. Doorbell with self-contained batteries.

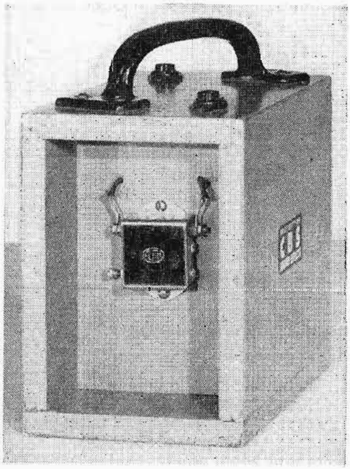

FIG. 7-43. Door buzzer with self-contained batteries.

Reverberation

Definitions

There are various ways of producing "echo" and reverberation. These two terms are used synonomously, but actually they are different. Echo is a distinct delay that reproduces the original sound once or several times over. Reverberation is a continuation of the original sound with no separation between the original sound and the continuation. The term "echo chamber" is used almost universally when actually it is a reverberation chamber.

Acoustical

There were various acoustical designs of echo chambers that have been used for years in radio and are still used in TV. With the advent of the so-called Hi-Fi sound, echo and reverberation have been used and *misused* to give music a big sound. Realistic acoustics of a large auditorium are difficult to reproduce synthetically without actually using the auditorium. One approach acoustically is to use a large hard-surfaced enclosure and feed this enclosure with a loudspeaker (see Fig. 7-45). The sound from the loudspeaker bounces around in this room enclosure and is picked up by a microphone in the same area. The output from this microphone is then mixed with the original sound, and a big sound is achieved (Fig. 46). Many have been designed for this purpose; included here are the specification for these designs.

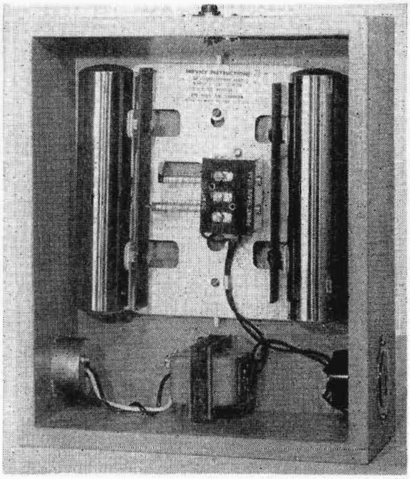
Fig. 7-44. Dual electric chime.

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The volume, shape, and acoustical characteristics of reverberation chambers are of prime importance as is the sound isolation afforded these units. Accordingly, as a minimum, the following precautions should be taken in their construction:

1. **Reverberation Time.** The reverberation time shall be as high as possible; i.e., rigid plaster walls finished with unpainted Keenes cement or equivalent shall be used.

2. **Sound Isolation.** Sound-isolating construction shall be employed for walls, ceilings, and floor to ensure a residual noise level of less than 30 db (ASA A weighting) under normal ambient-noise conditions.

3. **Room Location.** In order to alleviate the sound-isolation problem, reverberation chambers shall not be located close to potential sources of noise.

4. **Room Volume.** Room volume shall not be less than 2,000 cu ft and preferably larger.

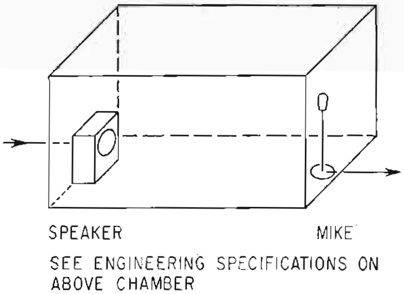

Fig. 7-45. Echo chamber—block diagram.

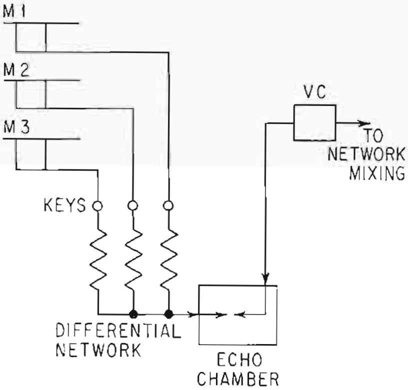

Fig. 7-46. Patching echo chamber—block diagram.

5. Room Dimensions. Rooms shall be roughly rectangular, but the ratio of any two dimensions shall not be a whole number or very close to a whole number (a ratio of length to width to height of 1.6 to 1.25 to 1.0 is generally found satisfactory).

6. Room Shape. No two walls shall be parallel to each other, nor shall the ceiling be parallel to the floor. Opposite surfaces shall be out of parallel by about 5° (approximately 1 in. in 1 ft). Preferably the walls and ceiling surfaces should consist of sections 4 to 8 ft wide and angled with respect to each other in accordance with the above.

Tape Echo

With the advent of three-headed tape recorders an electromechanical method of achieving echo was discovered. A very simple design of this type of echo is shown in Fig. 7-47. This machine, Centronix, has a record head which, when moved, can change the delay in echo. This makes it especially useful for various trick effects, etc. Most standard three-headed tape machines have all their heads fixed, so it is not possible to do too many tricks. Another design of tape echo which has found widespread use is the Audio Instrument machine. This design is very versatile in that a great variety of effects can be changed to get all sorts of reverberation and echo. This is shown in Fig. 7-48. The desired effect is a matter of end use.

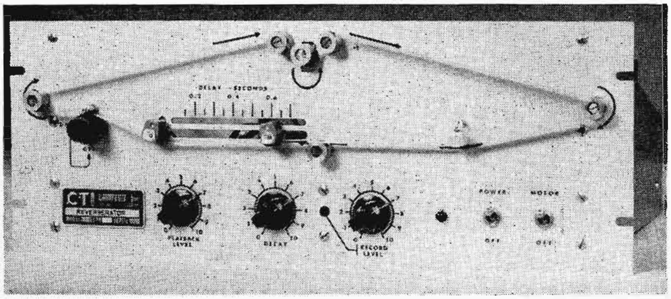

FIG. 7-47. Tape reverberation device. (*Courtesy of Centronix, Inc.*)

Piano Echo

A piano can be used for an echo effect by simply holding down the loud pedal and speaking into the strings (Fig. 7-49). This works quite well for dramatic effects but, of course, is difficult to control, as reverberation is quite long. This method was used in radio for many years.

Mechanical Reverberation

A very simple method of reverberation is shown in Fig. 7-50, where a bronze sheet is driven from one end and reproduced from the other end. This principle is very old. The trick is to get the sheet vibrating with the sound, and of course, since it is mechanical, it will take time for the sound to die out, which is the reverberation.

Figure 7-51 shows a professional unit type EMT-140 reverberation unit by Electronic Applications. This unit is already finding widespread use by the industry. There are undoubtedly many other designs which might be included here.

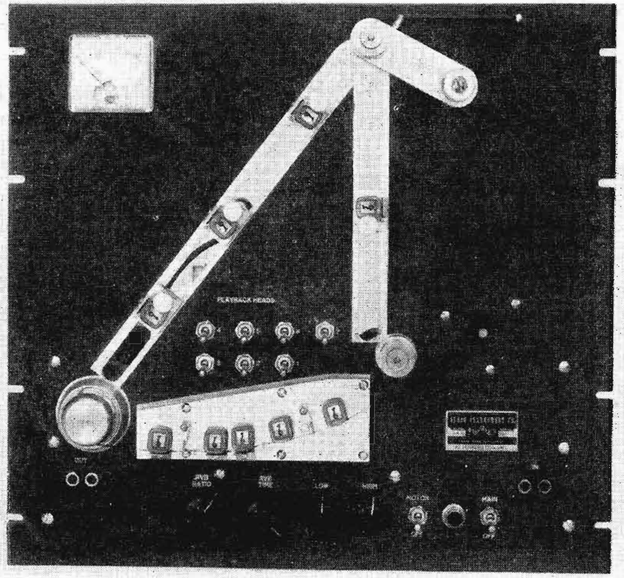

FIG. 7-48. Tape reverberation device. (*Courtesy of Audio Instruments.*)

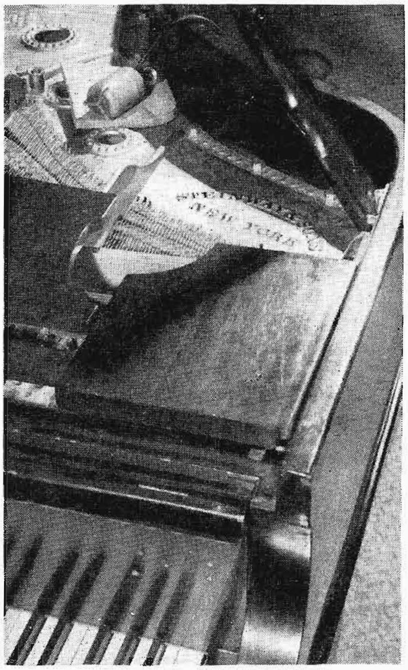

FIG. 7-49. Piano for reverberation showing mike placement.

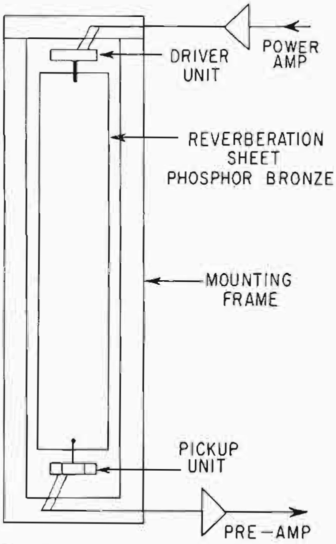

FIG. 7-50. Simple bronze-sheet reverberation.

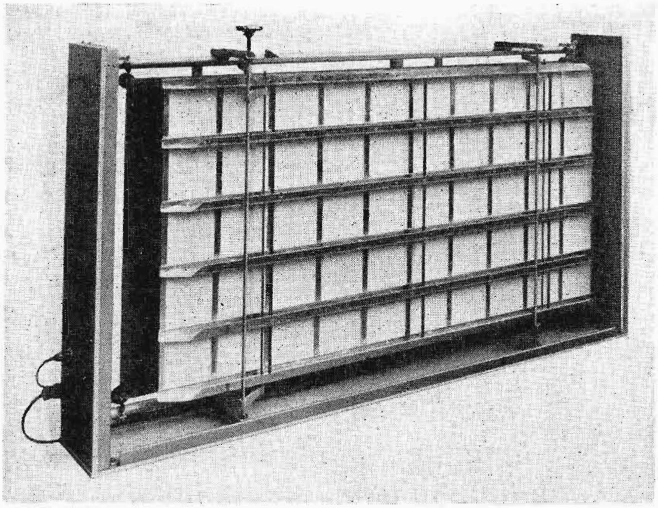

FIG. 7-51. Reverberation unit. (*Courtesy of Electronic Application, Inc.*)

Tape Devices

For many years there has been a definite need for an automatic tape loop device for sound-effects use that could be built with a number of multiple loops. The most difficult part of cueing sound-effects records is synchronizing these sounds with the picture. Once this is done, then repeating a cue while still trying to watch the monitor becomes a physical impossibility. Many suggestions have been made to use tape and record all the effects in the proper logical sequence. This is not too practical, however, as with a lot of effects, each one would still have to be cued as the previous effect finished. This would naturally require a lot of editing of tape, which would be expensive. In addition, as changes were made in the show from rehearsal to rehearsal, the sound-effects man would find himself thoroughly confused. He might find some effects deleted, timing changed, or some effects added. It is really more practical to have on tape only those things which have to be cued up very tightly to synchronize such as thunder, gunshot, explosion, automobile horn, etc. Continuous sounds such as traffic, rain, and water running can be cut in from a sound-effects record of a full cut of sound effects. Several tape machines of this type for quick cueing have been designed and built. One of the first was the so-called "laugh" machine, which had tape on the edge of 12-in. discs ¼-in. thick. These discs were under constant pressure to move but could not owing to a stop mechanism on the side of each disc. Upon pressing a key the disc was released and the tape traveled past a pickup head to give a reaction effect. This machine is fine for this audience-reaction type of work but would not be of much value in quick cues for sound effects. There was too much time between the start of the disc and the effect. In addition, changing tapes was difficult. A later model of this machine was designed with 16-mm tapes. This was not much better for sound effects but was all right for audience reaction. Since then several approaches have been tried and one model has been completed that works very well (see Figs. 7-52 and 7-53). Very short loops or loops up to 2 min can be used. The tape loop recues itself by going through its cycle and shutting itself off. The present machine has only three loops but is being changed to six loops. The only load the capstan must drive is the loop and a slight pressure to keep the loop taut as it passes the playback head. Cueing is very fast, with no wow or flutter of any sort. Transistorized preamplifiers are used throughout. Tapes can be changed quite rapidly. Using a tape machine to supply sound effects can be done with the turntables described. A block diagram (Fig. 7-54) shows how

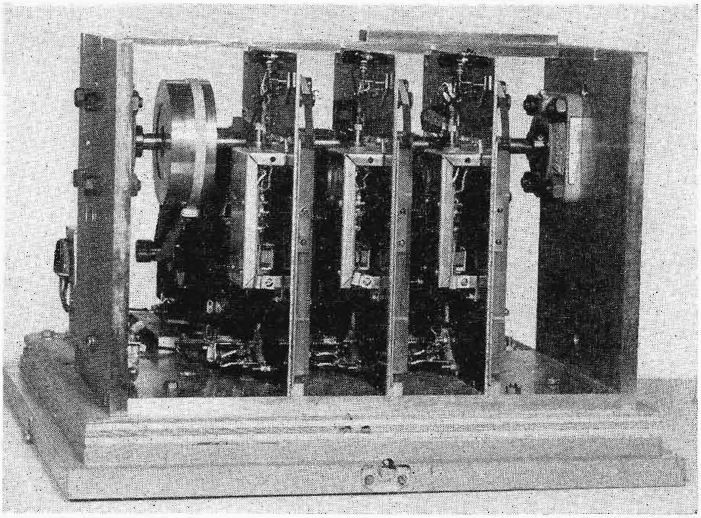

Fig. 7-52. Tape SFXer Binnie and Hartman design—front view.

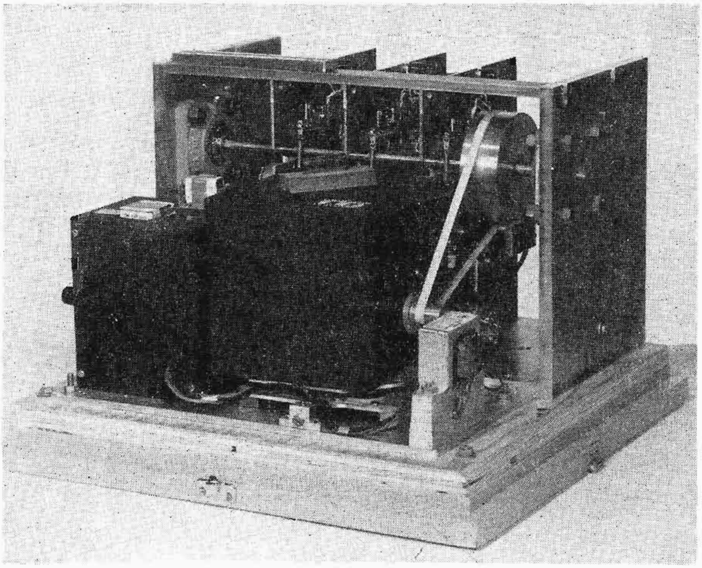

Fig. 7-53. Tape SFXer Binnie and Hartman design—back view.

this is possible. Once the effect is put on the tape and edited, splicing tape is used between effects so that progressively each tape is cued up. This will work if there is sufficient time to cue up between tapes, and of course, any timing changes during the playing of any particular tape will cause a loss of synchronization of that particular effect.

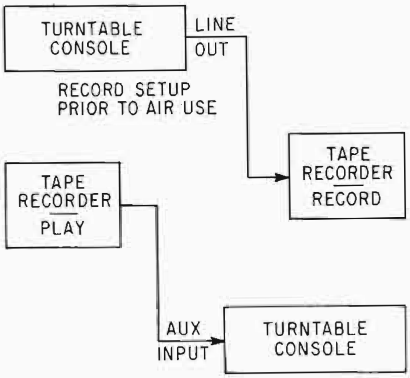

FIG. 7-54. Circuit showing output of console feeding tape recorder and also tape recorder feeding into console.

The output of the console can be fed to the record section of the tape recorder during rehearsal, so that sound-effects records can be dubbed to the tape to make up the necessary sequences. A very recent tape device in use today playing sound effects is the MacKenzie that is used at Disneyland and is a tape repeating device. This machine is shown in Fig. 7-55 and is excellent for sound-effects use. It has five magazines which are made up separately and can repeat individually. Cueing is very fast. This device should find many uses in sound effects as well as other fields.

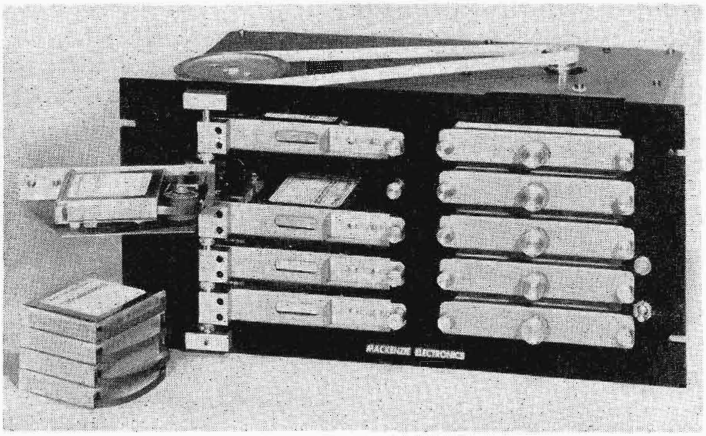

FIG. 7-55. Tape device. (*Courtesy of MacKenzie Electronics, Inc.*)

Other Electronic Effects

With the advent of LP records a more desirable type of portable record player was designed to be used by the sound-effects man. Inasmuch as sound-effects men are called on to play various types of music records as well as sound-effects records, especialy for backgrounds, cafes, night clubs, etc., this particular design was a must. This table uses a good four-speed turntable and a properly balanced and weighted arm so that LP and EP's can be played with good quality. Although not so elaborate as expensive turntables usually found in control rooms, it still has found a wide use because of its portability. For cueing purposes it is equipped with a transistorized amplifier that feeds a small speaker encased in the turntable case. This is shown in Fig. 7-56.

The "Boing"

One type of electronic "boing" that is widely used is in effect a guitar string that is stretched over a magnetic pickup. The pitch is varied by a handle on one end. Figure 7-57 shows this device. Another type that is used is the ordinary Jew's-harp. This takes an artist to play it, however.

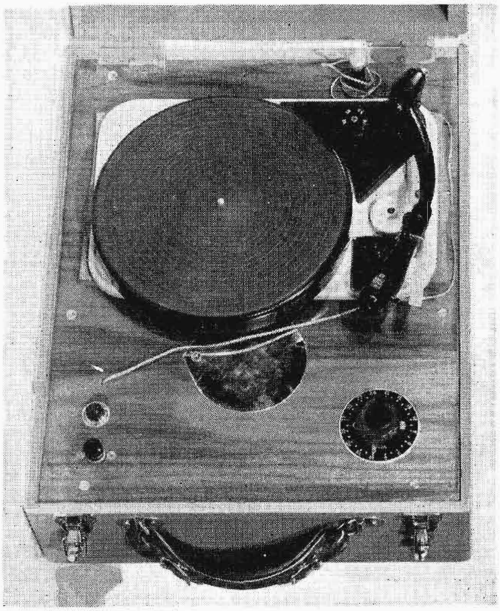

FIG. 7-56. Portable turntable for LP and EP as well as 78 rpm.

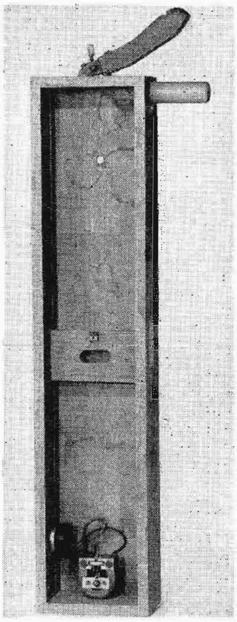

FIG. 7-57. Sound-effect "boing" showing steel string.

The Electronic Bat Crack

During the baseball season a good bat crack for sound effects is a necessity and something difficult to synchronize with a picture. But no more (see Fig. 7-58). This device uses a solenoid and tempo block operated by a foot switch. All the sound man must do is watch the monitor, and by stepping on the switch at the precise moment, he gets an effect of a bat crack. At the same time with his hands he operates his crowd-reaction records. It is not generally known, but most films of news events, except for actual speeches, are shot silent and the sound-effects man supplies all the effects. So during the baseball World Series rehash, he supplies all the effects on this news program.

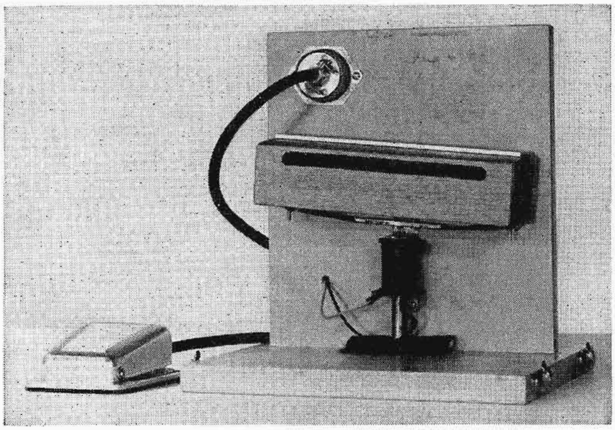

FIG. 7-58. Electric "bat crack" showing foot pedal.

Oscillators

Various types of oscillators are used in sound-effects work. Usually there is a demand for tones of all types. So everything from beat-frequency oscillators to single-tone self-operated types are called for. One type that found favor was the neon oscillator, shown in Fig. 7-59. This particular device was used mainly because it would not change pitch over a program but would remain on pitch. This was important as it blended with organ music.

FIG. 7-59. Neon oscillator for sawtooth tone.

Electronic Chime

A recently developed device which is finding many uses is an electronic chime. This device, shown in Figs. 7-60 and 7-61 uses three separate tone generators and three separate keying tubes. Any type of tone can be used, although in this case the tones are generated in a triode oscillatory circuit and keyed in as needed. Normally each keying tube is cut off, and when triggered, maximum sound comes through

FIG. 7-60. Electronic chime—three-note.

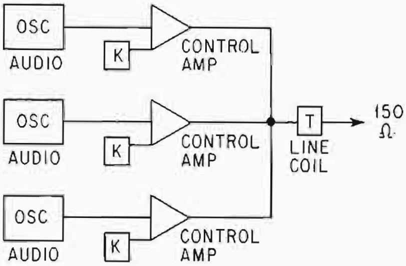

FIG. 7-61. Electronic chime—block diagram.

and fading is controlled by an *RC* circuit which can be almost any value to get the desired effect.

Manual Sound Effects

The Door

The sound-effects door that was designed for radio is also widely used in TV. Since this is a visual medium, the sound effects might look unnecessary. However, this is not the case. Quite often a door will open and close which will not be "on camera." Consequently the sound should be heard as indicated in the script. Otherwise, the story will not have continuity or meaning. Then quite often a door that is on camera or is visual may not sound like a door, or it may have the wrong latch on it or may be too far away from a mike to pick up the actual sound. In this case, once again the sound-effects door has to "fill in" the vacant sound. Occasionally a simple effect such as a knock on a door may cause a set to move or shake while on camera. Here once again the sound-effects man does the actual knocking, even though the actor may go through the motions. In Fig. 7-62, front, and Fig. 7-63, rear with screen, is shown a "door" that has been designed and constructed for radio and TV.

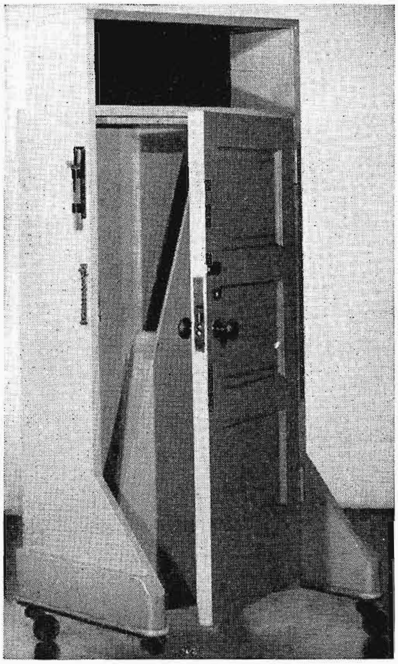

FIG. 7-62. Sound-effects door (front) showing door latch, chain, and acoustical chamber for resonance.

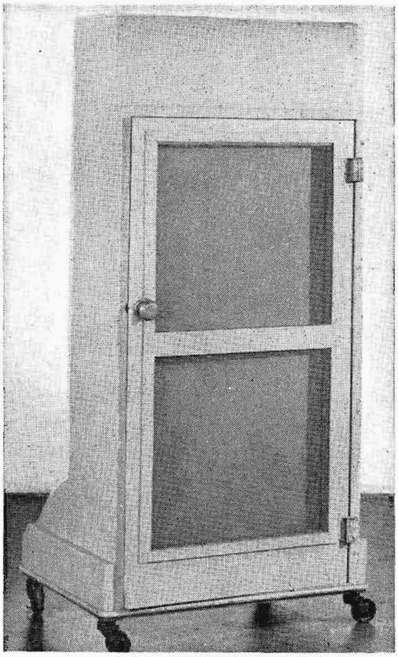

FIG. 7-63. Sound-effects door (rear) showing screen door.

The Sink

Another widely used device for sound effects is the sink. There is a sound-effects sink which is self-contained with a pump that provides running water from an actual faucet (Figs. 7-64 and 7-65). As can be seen in the exposed diagram (Fig. 7-66) this sink contains besides the sink a circulating pump, a reserve tank, a motor, and a vent and is connected with rubber hose to cut down noise. The motor must be running to provide running water. Consequently, used on the air this means it must be very quiet. The motor and pump assembly is cast heavy-duty and is shock-mounted on rubber mounts. The pump can run without having the faucet open, so that the pump has some pressure in the faucet before it is used. The reserve tank holds enough water so the sink can be filled if necessary. The vent allows this to happen without siphoning out the sink water. The entire cabinet is lined with sound-absorbing material 1 in. thick. The power switch is a mercury switch, so there will be no noise when it is switched on in a very quiet studio. This device is very useful in TV, since it is difficult to make sinks on camera practical.

Horses' Hooves

Coconut shells are used as much in TV as in radio depending on the script. Almost any effect which lends realism and can be controlled is actually much better done "live." Rubber plungers can also be used. Actually making a horse effect calls for good rhythm and coordination, and only a few people are gifted this way. When used with dirt or gravel as shown in Fig. 7-67, dirt should be wet down to avoid dust.

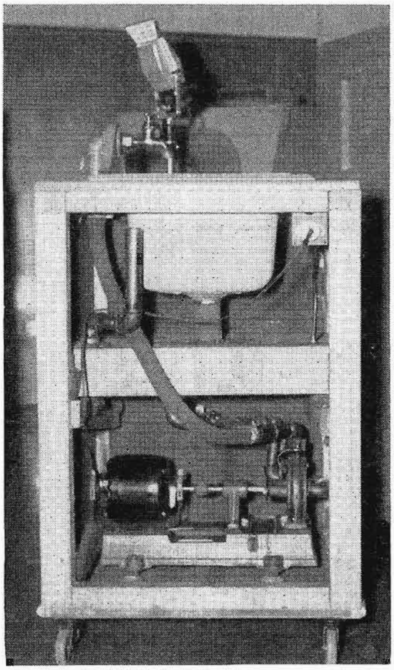

FIG. 7-64. Interior view of electric sink.

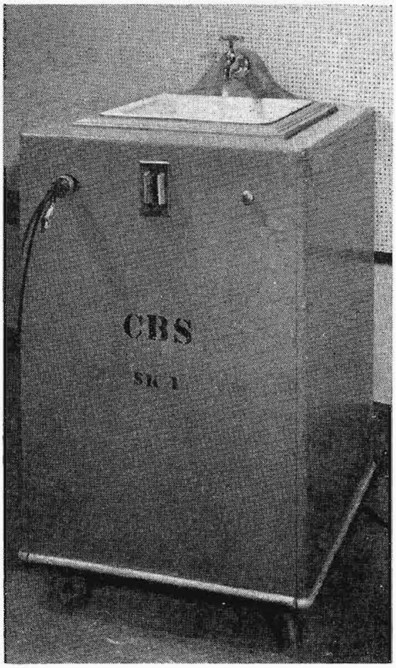

FIG. 7-65. Sound-effects sink showing running water.

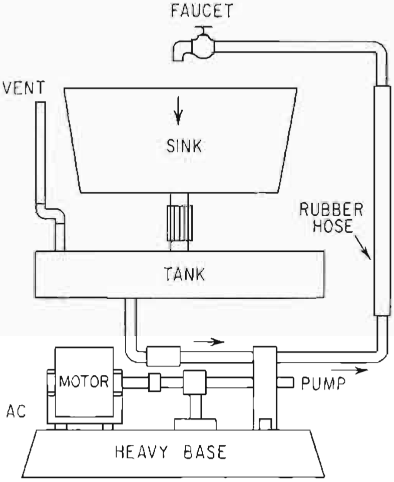

FIG. 7-66. Electric sink—block diagram.

Fig. 7-67. Horses' hooves in dirt box—using coconut shells.

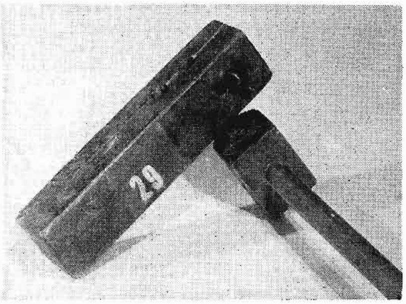

Fig. 7-68. Wood squeak for sound effects.

Door Squeak—Wooden

A wood squeak is caused by two dry pieces of wooden material rubbing together. A form of one type is shown in Fig. 7-68. Actually one end is in a dowel shape. This is moved in another piece of wood, preferably hardwood, and the squeak is adjusted by tightening down on the dowel. This must be adjusted to get a proper squeak. The whole assembly can then be put on a door with a temporary C clamp. This squeak can then be operated by a sound-effects man as in Fig. 7-69. This way the squeak does not have to follow any rigid pattern but can be different each time. One door for *Inner Sanctum* was actually built for just that show. So that no other show would use this door it was kept locked. When the show moved from one network to another, the door traveled with it.

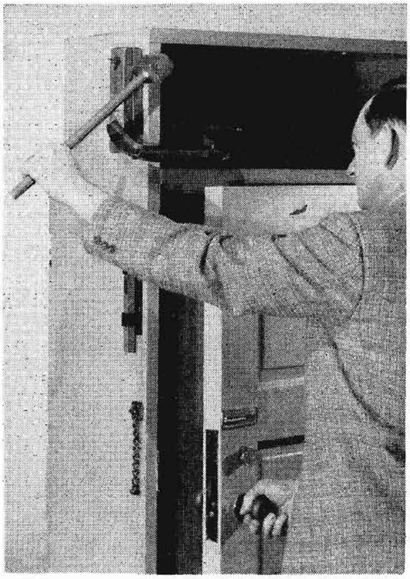

Fig. 7-69. Sound-effects door with wood squeak attached.

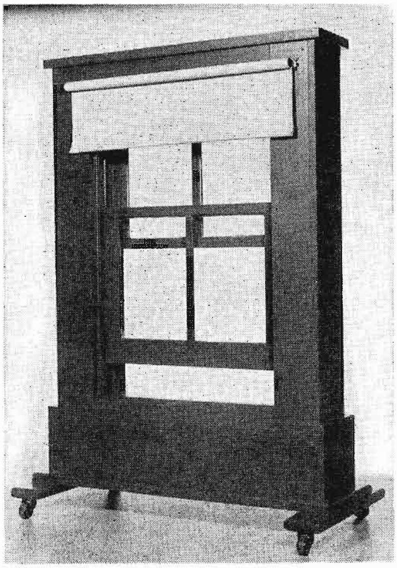

Fig. 7-70. Sound-effects window showing shade.

The Window

A device which is used quite frequently is the window. This is shown in Fig. 7-70. One window is hung with regular sash cord while the other uses chains to give a different effect. There is also a place for a window shade, as occasionally such an effect is needed.

Floor Boards

Most studios use concrete floors and tile. There is also a demand and need for wooden floor boards that are portable. A wooden floor board is used, of course, to show actual movement or footsteps, especially when there is no dialogue present (see Fig. 7-71). Quite a few directors insist on footsteps, so all sound men carry an extra pair of shoes for sound effects with hard leather heels. Footsteps are not

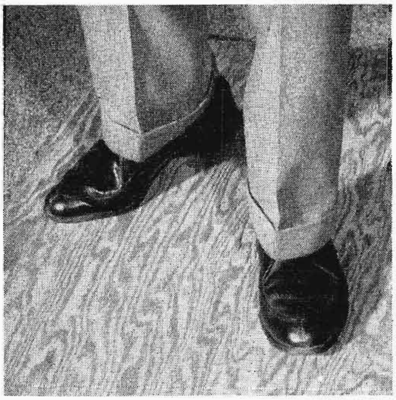

FIG. 7-71. Footsteps on a wooden floor board.

FIG. 7-72. Footsteps on a stone slab.

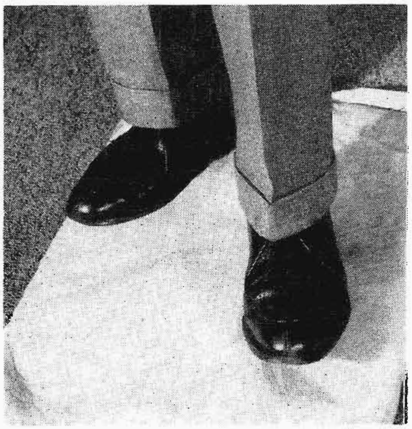

FIG. 7-73. Footsteps on gravel (in bag).

used so much in TV as radio, however, as it is possible to see movement and any fast movement such as running can actually be picked up with the actor doing the effect.

In addition to wooden floor boards, sound-effects men are called on to simulate walking on sidewalks. A marble slab about 12 by 24 in. can be used for this as shown in Fig. 7-72. Movement is expressed by walking in one spot up and down. Sound effects men are also called on to do footsteps on gravel, sand, snow, metal floors, brush—and you name it. Note in Fig. 7-73 steps on a gravel bag. The gravel is contained in a double canvas bag so that the sound will come out but not the gravel. This way there is no mess or spilled gravel on the studio floor. However, if the director insists, the bags can be opened easily and the gravel can be spread out on a canvas over a larger area. In a similar manner bags can also contain cornstarch to get an effect of walking on snow, or a small cardboard box of cornstarch well wrapped can give the same effect very close to the sound-effects microphone. The box is squeezed by hand. Occasionally an effect of walking in brush or through trees is called for, in which case broom straw is used. This can be done by hand or can actually be walked on if there is sufficient room.

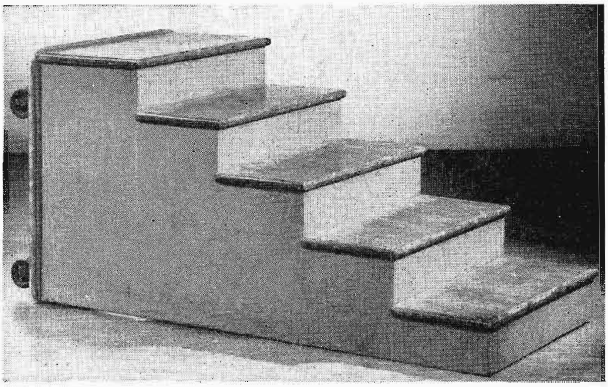

FIG. 7-74. Sound-effects stairs (portable).

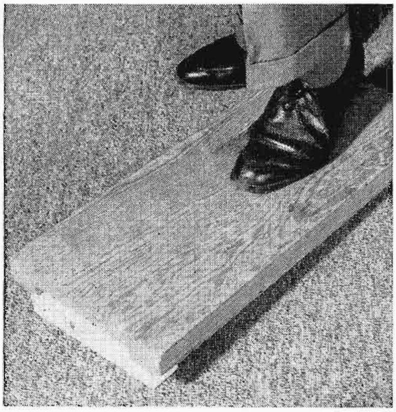

FIG. 7-75. Footsteps on a slanted board for stairs effect.

Stairs

Wooden stairs are called for occasionally, and a set is shown in Fig. 7-74. If these are not available, there is a simulated effect which can be got from a floor board or a slanted board as shown in Fig. 7-75. Since the board is slanted, it is impossible to walk flat on it, so the foot slides onto it as in the case of stairs and the heel sound is not heard—only the sole of the foot.

Glass Crash

This shows a type of manual glass crash that actually breaks a piece of glass. Window glass is supplied in an 8 by 10 size, and when one or two sheets are placed in this frame, it can be broken by pushing down the lid of the machine (see Fig. 7-76).

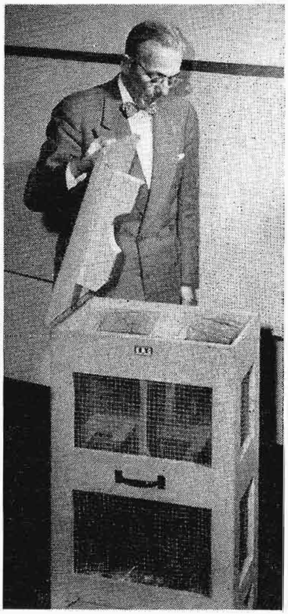

FIG. 7-76. Glass-crush machine.

Prop Table

A very important item that is used on practically every show is a prop table. Prop tables have been designed in a number of ways. This table has a cork top so that it is quiet and durable. The height is a matter of practical mike placement on one side and the height of the sound man on the other. Besides holding props, this table can be used for such things as a body fall with elbows and arms landing on it.