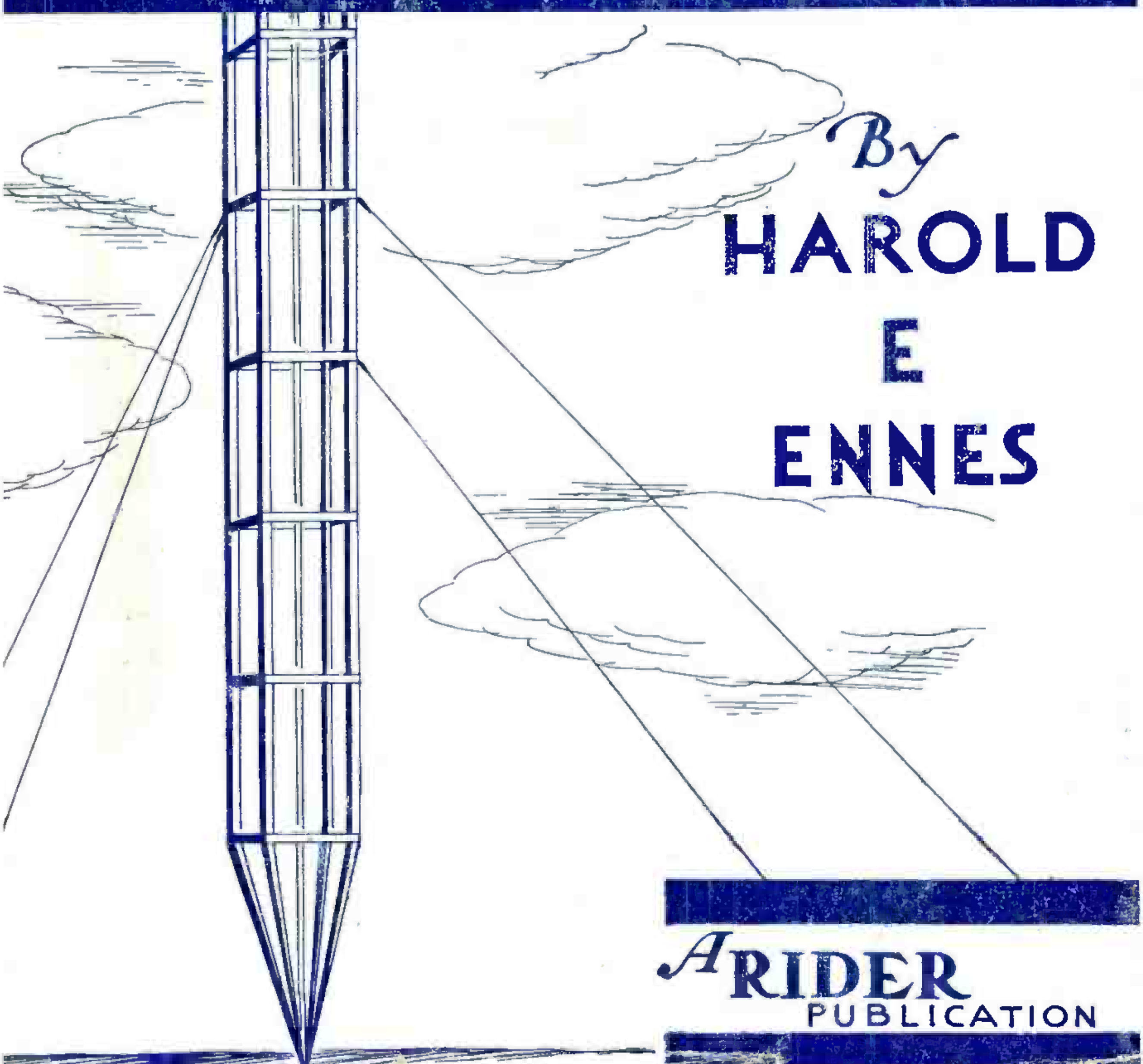
BROADCAST OPERATORS HANDBOOK



By

HAROLD E ENNES

A RIDER PUBLICATION

BROADCAST OPERATORS HANDBOOK

By Harold E. Ennes

Staff Engineer,
Indianapolis Broadcasting, Inc.

Since 1921, when the start of broadcast stations as a specialized field of radio were realized, the industry has undergone many changes that would take many volumes to record. Transmitting and receiving equipment have reached a state of fidelity of tone that the comparison to "canned music" is no longer descriptive of the art. Studios have reached a state of development that has almost hopelessly antiquated those of a few years back. Production of complex musical and dramatic shows on the air has reached a peak that marks a transition from an old into a brilliant new era.

While all this development of almost flawless equipment has been occurring, literature between this field of radio engineering and practical operation of the equipment, shows a wide gap. And this is particularly true in the field of broadcasting with the exception of equipment design engineering. It is to fill this gap that this book was written.

The first four parts of the book cover the operating practice in control rooms, the master control, remote controls, and the transmitter; the fifth and sixth parts discuss technical data for operators and technicians, including comprehensive preventive maintenance instructions; operational data for transmitter meters and indicators are included in the Appendix.

Mr. Ennes, an operator, writes in the operators' language. Intended not only for the newcomer in the broadcasting field, this book will appeal to the old timer as well, who will find many ideas in it that will give him a new and refreshing slant on many phases of his job of putting programs on the air in the best possible way.

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JOHN F. RIDER PUBLISHER, INC.
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TO
BARBARA JEAN

INTRODUCTION

THE RADIO INDUSTRY has been called one of the great giants of our age. Actually, its strides into virgin territory have been almost beyond prophecy. Since 1921, when the beginnings of broadcast stations as a specialized field of radio were realized, this industry has undergone a convulsion of changes that would take thousands of volumes to record. Transmitting and receiving equipment have been made to realize a state of fidelity of tone that the comparison to "canned music" is no longer descriptive of the art. Studios have reached a state of development that has almost hopelessly antiquated those of a few years back. Production of complex musical and dramatic shows has reached a peak that marks a transition from an old era into a brilliant new one. And still the upheaval goes on, all eyes are still ahead, all energies still expended in further development.

All this is not surprising. Development of almost flawless equipment seems taken for granted by this scientific generation of young and old alike. The surprising aspect is the obvious gap in literature that exists between this field of radio engineering and design, and the practical operation of their products under actual use. This is especially true in the field of broadcasting. Probably this is due to the somewhat limited circle of engineers who are concerned with broadcast operations; yet there is no subject of interest more expansible or inexhaustible.

Part 1 of this book is thus intended primarily to be a comprehensive treatise of control-room operation for broadcast technicians, endeavoring to collect enough coordinated facts to result in a general set of rules to serve as standards of good operation practice. An attempt is made to bring forth a new approach to modern operating technique, and to discuss and clarify existing facts that should lead to a better understanding between studio and transmitter personnel. The discussion necessarily includes an analysis of different types of indicating meters used in practice, in order that their functions may be more clearly interpreted and understood in relation to the work which they are intended to perform. Related subjects, such as loudness sensation for a given meter reading, waveform, and phase shift in studios, are analyzed.

The subject and content of this book are intended not only for the many newcomers to control rooms and transmitters, but also for the "old timers," familiar with all the problems peculiar to their work. The first four parts cover the operating practice in control rooms, the master control, remote controls, and the transmitter, and the fifth and sixth parts are concerned with technical data for operators and technicians.

Station setups must inevitably fall into two general classifications: the "smaller station" design, where control room and master control are combined on one centralized console with studios grouped about it, and the "larger station" setup, with individual control rooms for each studio, and master control as the central switching unit.

The book has been so arranged in order to present the material on each subject in as thorough a manner as possible, and will be equally applicable to either type of technical setup.

ACKNOWLEDGMENTS

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Chapter 20 contains in part material appearing in articles by this author in RADIO during January, February and March of 1945, and is reproduced herein through the courtesy of Radio Magazines Inc. The entire book is based on the authors' original article "Some Suggestions for Standards of Good Operating Practice in Broadcasting," RADIO, August, September and October, 1943. Part 4 contains some data from the author's "Operational Engineering for Broadcast Transmitters" in COMMUNICATIONS.

The author is also indebted to Mr. Joseph Kaufman, Director of Education at the National Radio Institute for his sincere desire to see such a book as this published, and his courtesy in allowing the use of part of the material herein that was written by the author for the new broadcast section of NRI home study courses.

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HAROLD E. ENNES

November 22, 1947

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BROADCAST OPERATORS HANDBOOK

Part 1

OPERATING IN THE CONTROL ROOM AND STUDIO

Chapter 1

WHAT YOU'RE UP AGAINST

BROADLY SPEAKING, there are three kinds of pickups which concern the control-room operator; namely, studio, remote controls, and incoming network programs where the station is affiliated with a particular network.

Studio programs are all programs that originate at the regular station studios. All the most popular shows, such as Jack Benny, Bing Crosby, and Fred Allen, are studio programs at the main network studios. These same shows, of course, are handled as incoming network programs at the affiliated stations.

A remote control, or "nemo" in radio language, is a pickup originating somewhere other than the stations' regular studios, such as a sporting event or night club. Remote controls will be discussed in Part 3 of this book.

For studio programs, microphones must be set up or "spotted" in the studio in such a manner that all musical instruments and performers that are part of the production will be adequately covered. Sound waves striking the movable element of the microphone causes a vibration in the magnetic field in which the element is suspended, which in turn results in an electric potential on the element varying in accordance with the sound waves. The mechanical construction of various types of microphones used for broadcasting is explained in Part 6 of this handbook. The electric energy thus generated is very weak and must be amplified to an amount sufficient to be carried by wire lines to the transmitting plant. (This is true in all cases except in some of the lowest powered installations where the transmitter and control rooms are installed together. Even when this is true, the signal must be amplified considerably to drive the speech input stages of the transmitter.) Control of the various microphones is provided by grouping individual switches and volume controls for each microphone on a panel known as the *control* console. A volume indicator must be used to indicate the relative magnitude of the program signals and is mounted in a convenient visual area on the control console.

Control Operator

One duty of the control operator is to place the microphones in the studio where the production director wants them for a particular program. Where no production director is employed, the control operator must determine the positions of the microphones, or, perhaps more correctly stated, he must determine the positioning of the performers in the microphone pickup area. The best positions are usually determined only by rehearsing the show before air time, and alternating the respective positions until the proper pickup is achieved.

During the progress of a studio show, the studio operator's position is at the control console. It is his function to operate the various microphone controls so that their respective outputs properly "blend" into the effect desired. When a production director is employed at a station, he will assist the operator by telling him which sound or sections of sound to "bring up" or "lower." Since, in any transmission system, definite limits exist as to maximum volume that can be han-

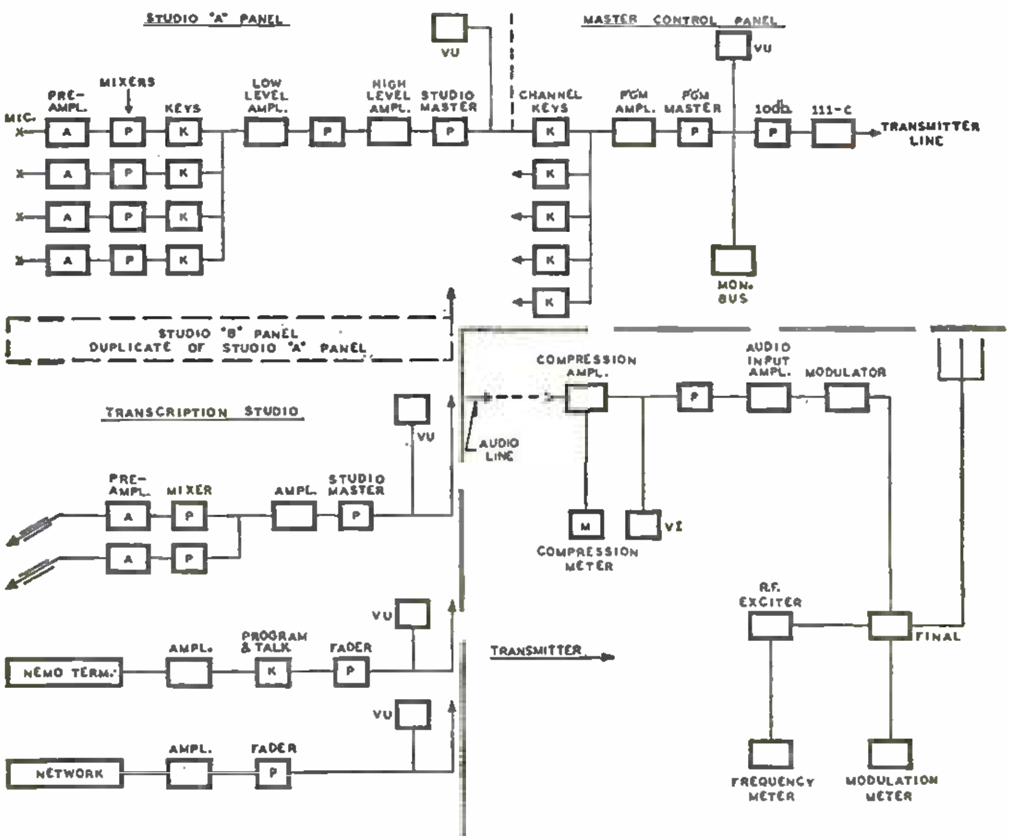


Fig. 1-1(A). Block diagram of a typical broadcast station installation, showing various setups for switching to different studios and remote and network lines, monitoring, etc.

dled and minimum volume that is adequate for transmission, the overall volume must be monitored and controlled by the operator. This is the purpose of the volume indicator. The operator must also operate the switching system to choose the proper studio or incoming program lines. Technical features of typical control consoles and switching systems are considered in Part 6 of this handbook.

A good studio operator must not only be familiar with the technical equipment, but also be very sensitive to art as well as science in broadcasting service.

Studio and Transmitter Installation

In order to visualize more clearly some of the discussion to follow, it will be helpful to refer to the block diagram of a typical broadcast installation as shown in Fig. 1-1(A). Most of the illustration is self-explanatory, showing in simplified form the setup necessary for mixing

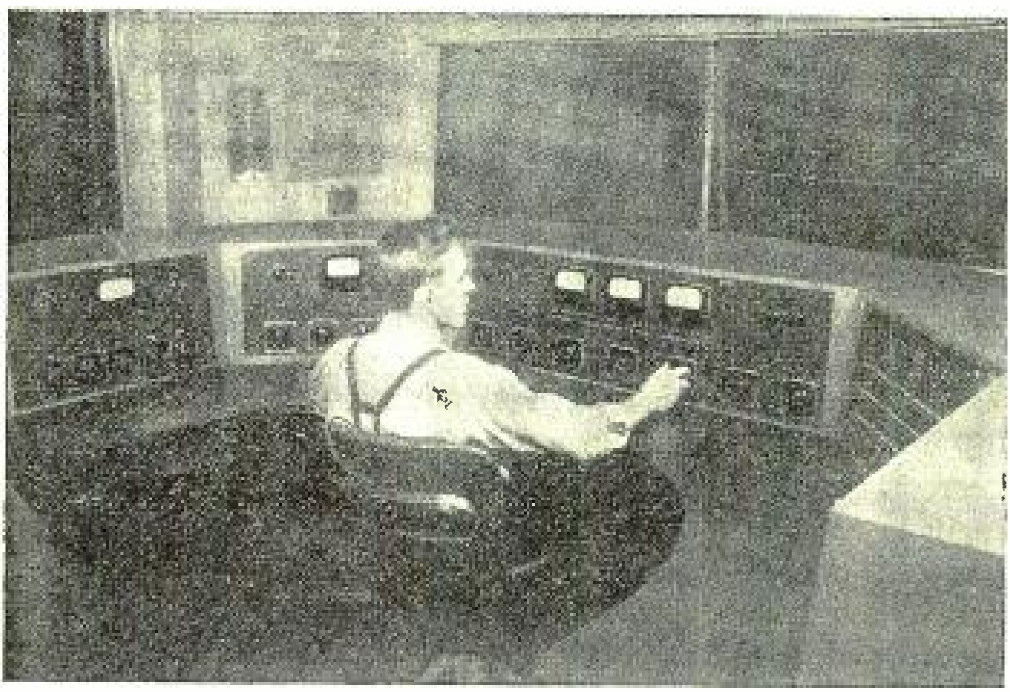


Fig. 1-1(B). The control console of Fig. 1-1(A). The master panel is in the middle with studio panels on either side.

and blending of voice and music from a specified studio, switching of studios, "remote" and network lines, visual and aural monitoring facilities, wire transmission to the transmitter, and associated equipment. A photograph of this centralized control installation is shown in Fig. 1-1(B).

The pad *P* shown in the master control panel circuit before the *111-C* repeater coil is inserted to provide a constant load at all times for the channel amplifier, and is necessary since the equipment sometimes operates at a higher level than is deemed advisable to feed into program lines of the telephone company. The new standard vu meter bridged across the monitoring points are supposedly indicators of 1 milliwatt of power (sine-wave) in 600 ohms. Actually, the meter indicates 0 vu with a sine-wave power at 1000 cycles of between +4 vu and +26 vu, depending on the external resistance used in series with the meter to allow greater bridging characteristics, and to facilitate adjustments to correlate readings of the meters used at slightly different volume levels in the circuit. Rms meters of greater sensitivity have not proved practical to date. It should be kept in mind that this calibration assumes a sine-wave signal, and that under actual program material of energy sufficient for 0 vu deflection, instantaneous peaks will exist of several times 1 milliwatt energy, and average power will be a fraction of 1 milliwatt.[1]

As may be observed from the block diagram, visual indication of the program in progress is provided on the studio panel, the outgoing channel amplifier, the line amplifier at the transmitter, and the final result, monitoring of percentage modulation of the transmitter. The duties of the control operator include not only the "spotting" of microphones for musical and dramatic pickups, switching of studios and lines on scheduled time or cue words, and proper mixing of voice and music on studio setups; but also making certain that his "reference volume" or zero volume level does not exceed that point to which 100% modulation of the transmitter is referred.

"Zero volume" level is simply an arbitrary point, and is not to be thought of as rigid fundamental electrical units of power, current, or voltage. It is necessary that it be understood only in relation to the electrical and dynamic characteristics of the meter used and the technique of reading its response. Perhaps this will be clarified by Fig. 1-2, showing the response of two typical volume indicators on a sudden applied signal. This difference in dynamic characteristics of the new and old type volume indicators (Fig. 1-3) shows the need for a difference of technique in using the interpretation of the meters. The standardization of the new type indicator is a great step forward in broadcasting and most stations are equipped with these meters today.

[1] Chinn, Gannett, and Morris. "A New Standard Volume Indicator and Reference Level," *Proceedings,* IRE, January 1940.

It must be remembered, however, that modulation monitors at the transmitter must necessarily be of the semi-peak reading type since this is specified by the FCC (Federal Communications Commission); whereas, the vu meter used at studios is meant to integrate whole syllables or words. This meter is slightly underdamped, which tends to cause the pointer to pause for a moment on the maximum swing, then start downward more slowly than in the case of the previous indicators. Therefore the meter appears to "float" on the peaks without any erratic jumps. The psychological effect is excellent and the meter

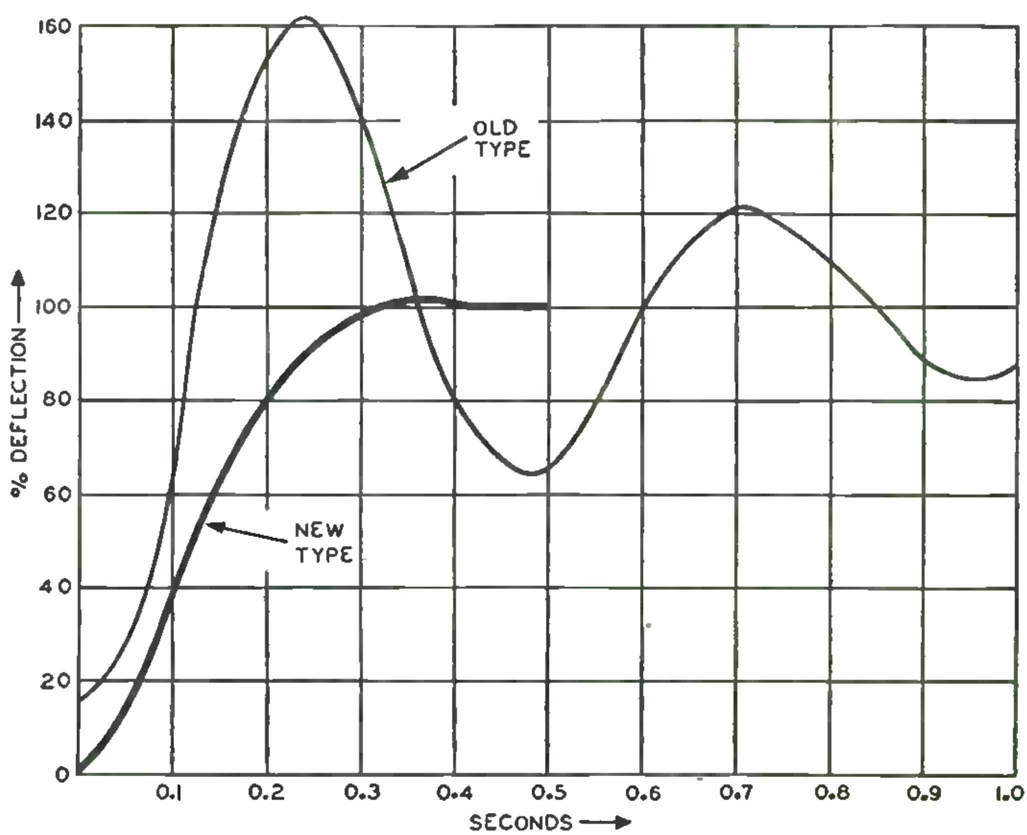


Fig. 1-2. The response of old and new types of volume indicators to a suddenly applied signal indicates a need for a different technique in the interpretation of the readings. *Courtesy Proc. IRE*

appears to show the audio wave as it sounds to the ear from a monitoring speaker. A typical transmitter modulation meter reaches 100 on the scale in approximately 0.09 second when a 1000-cycle voltage of the required amplitude is applied to the equipment; whereas the vu indicator reaches 99 in 0.3 second, as indicated in Fig. 1-2.

Coupled with this difference of dynamic characteristics of the two meters is the conventional habit of monitoring at the transmitter on a single positive or negative peak. By studying Fig. 1-4, which is a graph drawn from a typical oscillograph of a speech wave, it is noted that the energy in positive and negative peaks is far from equal. This is typical of speech waves at the output of a microphone regardless of the type or make of microphone used. Since the vu meter works from

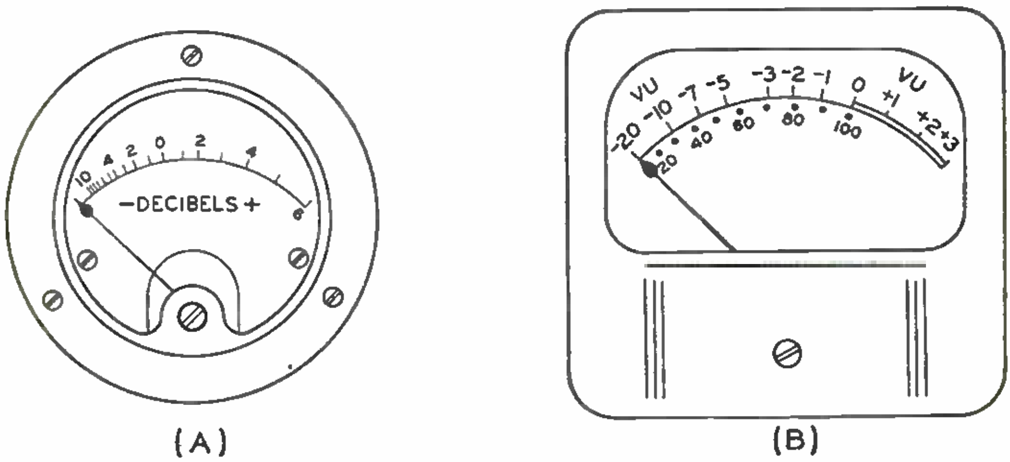


Fig. 1-3. The old type of volume indicator is shown at (A) and the new type at (B).

a balanced full-wave rectifier, its reading is not dependent on the pole of operation, and thus the comparison of the indication at the transmitter modulation meter position with that at the studio cannot be expected to agree even with perfectly matched circuits between.

This one fact is probably the most universal reason for friction between transmitter and studio personnel. It is not possible, for instance,

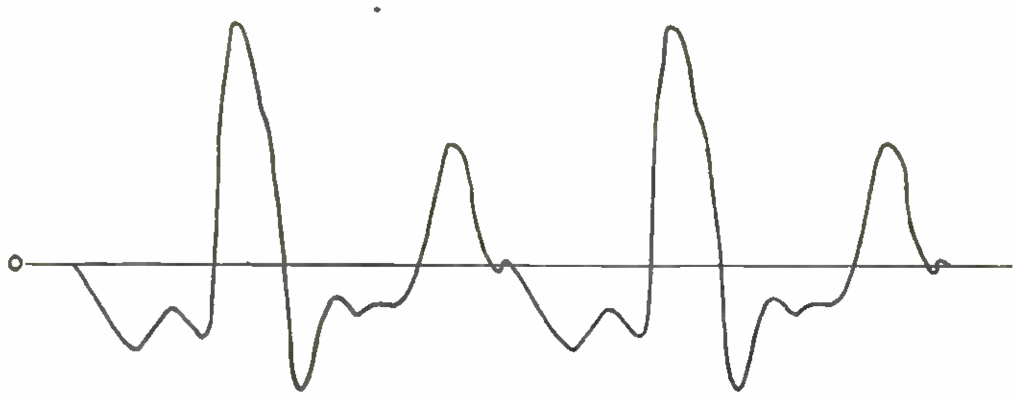


Fig. 1-4. This representation of a typical speech wave shows that the energy in the positive and negative peaks are unequal.

to obtain the same polarity of maximum energy from the two sides of a bidirectional microphone. An interviewer may show an indication at the transmitter of 100% modulation and the interviewee on the opposite side of the microphone (therefore oppositely poled at the microphone transformer) may show only 50% (or less), yet the indicator at the studio (full-wave rectification) will show exactly the same peak level. It is perfectly plausible then that the transmitter operator unfamiliar with speech-wave characteristics through a microphone should conclude from his monitor reading that the two voices are not balanced at the studio end. This belief is sometimes further encouraged by the extreme difference of "loudness sensation" between two voices of different timbre that are peaked the same amount on a full-wave rectifier indicator. This discrepancy between level indication on a meter and the aural "on air level" is one of the most perplexing problems of broadcasting and will be taken up in more detail presently.

Transmitter Operating Technique

The foregoing discussion brings to mind several questions as to transmitter operating technique. Is there any true indication at the transmitter of comparative levels from the studio? Which pole of the modulation envelope should be monitored continuously and why? These problems, together with detailed suggestions of pre-program level checks will be discussed in Part 4 on transmitter operating practice.

As will be discussed under the transmitter section, it is highly desirable to have all the undirectional microphones in use at the studio poled so that the maximum energy pole of operation will coincide with the positive side of the modulation envelope at the transmitter. The ratio of peak energy difference varies with type and make of microphone, but is apparently most pronounced in pressure type microphones, such as the RCA type 88-A. This type microphone, due to its light weight and rugged construction, is often used for remote pickups, and in studios, such as transcription booths, used mainly for announcements. The operator should always take advantage of this characteristic when this type microphone is used, as the results of proper polarization at the studio are very much worth while.

Loudness

As to the problem of difference in "loudness sensation" for a given meter reading between two or more voices, a brief perusal of the situation will emphasize the magnitude of its importance, and should constitute a challenge to operators and engineers to correlate existing facts with operational procedure.

Fig. 1-5 is a graph of loudness level curves as adopted by the American Standards Association. The derivation of these curves is explained in most standard textbooks on sound and will not be duplicated here. An example will suffice to enable the reader to use this graph correctly. It will be noted, for example, that a tone of 300 cycles, 40 db above the reference level (0 db) corresponds to a point on the curve marked

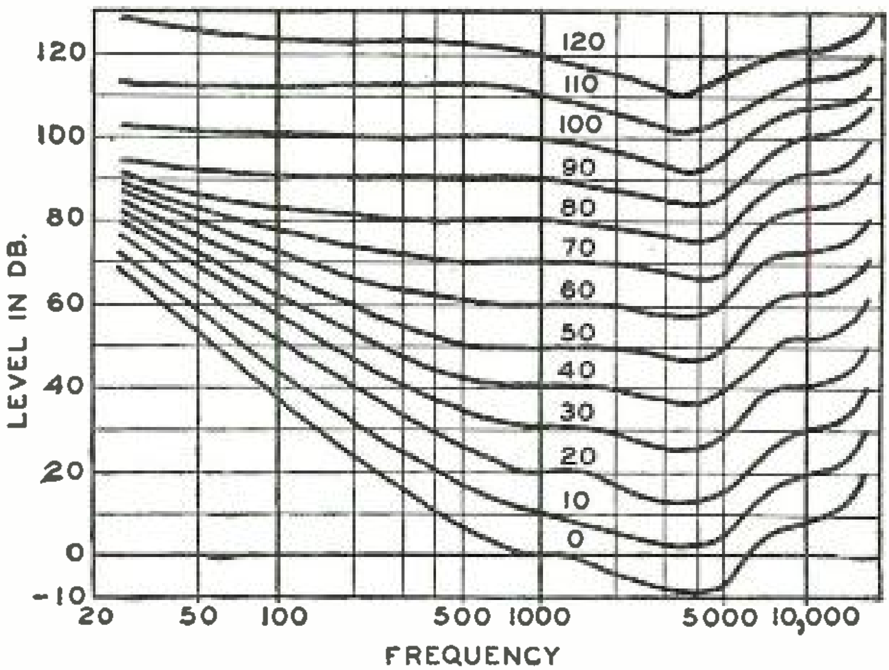


Fig. 1-5. Family of loudness level curves as adopted by the American Standards Association.

30. This is then the loudness level. It means that the intensity level of a 1000-cycle tone (reference frequency) would be only 30 db in order to sound equally loud as the 40-db 300-cycle tone.

Now assuming a fundamental of 392 cycles (G-string of a violin) with an actual intensity of 40 db above reference level, it would be noted from the curve that the loudness level is approximately 36 db. It was determined in Bell Laboratories that the addition of the overtones or harmonics of the fundamental raised the intensity from 40 to 40.9 db, whereas the loudness level was raised from 36 to 44 db. In other words, the addition of the harmonics raises the actual meter reading only 0.9 db, while the loudness level *increases 8 db.* For the complex tone, the reference level of 1000 cycles would be 44 db to sound equally loud.

When it is realized that the vocal organs of human beings are all exceedingly different, and are associated with a particular resonating apparatus that gives to the voice its individual timbre, it becomes clear why it often occurs that two voices peaked at a given meter reading will sound far different in loudness. Certain harmonics of the voice are emphasized while others are suppressed in an infinite variety of degrees. A study of Fig. 1-6, which illustrates a graphical integration of two male voices intoning the same vowel, will reveal a decided

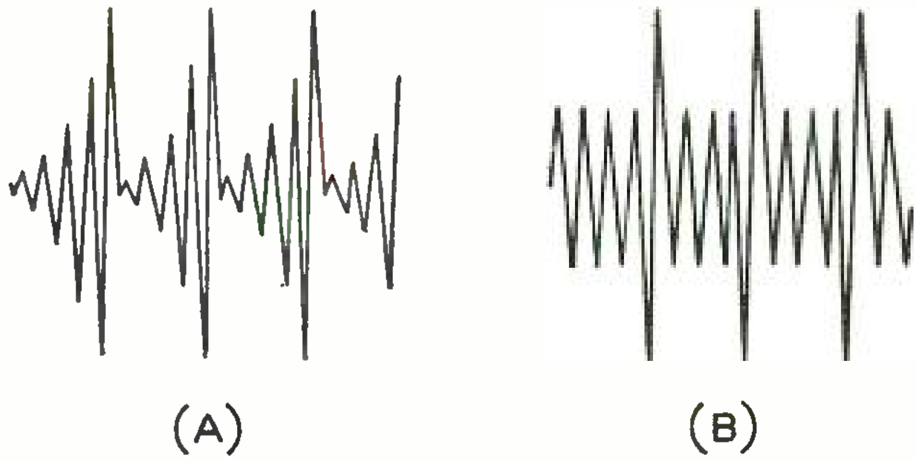


Fig. 1-6. Graphical integration of two male voices intoning the same vowel that discloses a great difference in the peak factor of each.

difference in peak factor (ratio of peak to average content), which in turn depends to a large extent on harmonic content and phase relationship of the harmonics to the fundamental.

At the present time only one solution suggests itself. When it becomes necessary to transmit two voices of such difference in timbre as to be decidedly unequal in loudness for a given reference level, the good taste and judgment of the operator at the control panel must govern their respective levels. The author fully realizes the many and varied complications that arise from this condition, since loudness is not only a physical, but also a psychological reaction. The level at which the receiver in the home is operated will determine the extent to which changes in loudness intensity are noticeable, since at low volumes greater change of intensity is required to be noticeable to the ear than is the case at higher volumes. Acoustics of the studio and the room in which the home receiver is operated will influence the ear's appreciation of level intensity changes. However, the control man with good taste, a critical ear, and keen appreciation of values can find the "happy medium" between aesthetics and conventional transmission operations. This is of prime importance when voice and music are to be blended, as will be discussed later.

Details of Control Room Metering Circuits

A few of the fundamental characteristics of broadcast metering circuits have been discussed in relation to the proper understanding of their functions by both control room and transmitter personnel. The operator employed in broadcasting is confronted with the handling and measuring of the quantity known as the "volume" of sound. His conception of volume must necessarily be influenced by other than precise mathematical relationships of electrical units such as power, voltage, or current. At the same time, his means of measuring the complex and nonperiodic speech and program waves must be based primarily on a-c theory in terms of the related values of sine-wave currents. The correlation of data on program metering circuits to serve definite performance characteristics for various parts of a transmission system is a most important subject and yet perhaps the least understood among the operators and technicians concerned with their use.

Since the earliest days of electrical program transmission, about 1921, when it became apparent that distortion due to overloading of an amplifier was far more noticeable in a loudspeaker than in the ordinary telephone receiver, various schemes for measuring the magnitude of program waves have been developed. The first device was a d-c milliammeter connected in the output of a triode detector, with an input potentiometer to adjust the sensitivity in 2-db steps. Thus, by adjustment of the sensitivity control so that peaks of program waves caused an indication of approximately mid-scale on the meter at intervals, and by operating the telephone repeaters at about 10 db lower on peaks than the point of overload, a visually monitored program circuit became a reality.

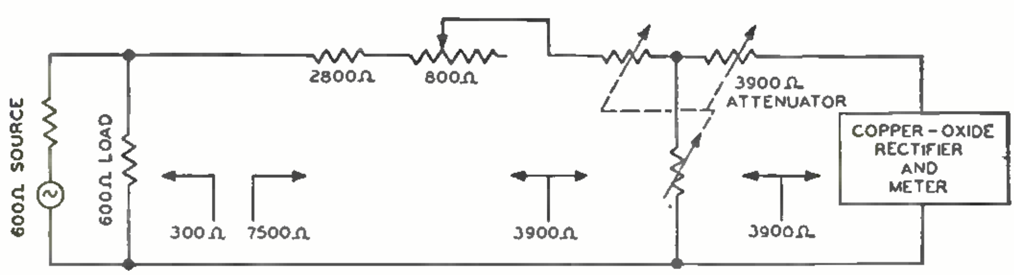


Fig. 1-7. Circuit that is used to bridge the new vu meter across program lines or individual studio output lines.

From this early start, there developed a long series of devices, some with tube rectifiers, others with dry rectifiers (peak and rms indicating), full- and half-wave rectification, all degrees of damped movements, and calibrated with reference levels of 10^{-9}, 1, 6, 10, 12½, or 50 milliwatts, in 500 or 600 ohms impedance. It was not until 1938 that the Bell Telephone Laboratories, the Columbia Broadcasting System, and the National Broadcasting Company pooled their knowledge and problems in a joint effort to develop a standardized volume indicator with the reference level implied in the definition of volume units.

The outcome of this concentrated study was the new standard vu meter such as those on the control panel of Fig. 1-1(B). The schematic diagram of Fig. 1-7 shows the circuit used to bridge the meter across program lines or individual studio output lines. It is seen that the total impedance presented to the line is about 7500 ohms; 3900 ohms in the meter and about 3600 ohms supplied externally to the meter. The dynamic characteristic is also standardized as mentioned earlier, being such that, if a 1000-cycle voltage of such amplitude as to give a steady indication of 100 on the voltage scale or 0 db on the decibel scale, is suddenly applied, the pointer will reach 99 in 0.3 seconds and overswing the 100 mark by not more than 1.5%. This meter is a great improvement over previous volume indicators where large amounts of overswing often occurred.

The graph of Fig. 1-4 is a representation of a speech wave taking place in the time interval of 1/100 second. It is obvious that due to mechanical inertia of meter movements, true "peak reading" indicators are impossible in the strict sense of the term. Since the copper-oxide instrument, indicating rms values, is sufficiently sensitive without the use of vacuum tubes, and since in the final analysis, the indication on the meter should follow as nearly as possible the psychological effect of hearing, this type indicator has been standardized for control room and line transmission use. Although peak-reading indicators are much faster than rms instruments, in actual practice their accuracy is limited to about 100 cycles per second. At the higher frequencies their function is to integrate the speech occurring over a period of time.

As will be discussed in detail in the transmitter section of this handbook, the FCC specifies some form of semi-peak indicating meter to measure modulation percentage at the transmitter. This is necessary since the peak factor (ratio of peak to rms values) of program waves may be 10 db or more, and when these peaks occur in rapid succession, danger of breakdown in circuit components exists as well as the occurrence of adjacent channel interference. Means must also be provided to check positive or negative peaks of the modulated carrier. Thus the modulation monitor is essentially a half-wave rectifier indicator. These differences between studio and transmitter meter characteristics must always be borne in mind by the operators.

Volume Indicator Interpretations

For the purpose of discussing the problems relating to use and interpretation of volume indicator readings, the well-known fact that any wave, no matter how complex, may be reproduced exactly by a number of sources of pure tones will be employed.

Fig. 1-8(A) shows two simple harmonic motions of the same frequency, differing slightly in phase; that is, tone *b* is lagging behind

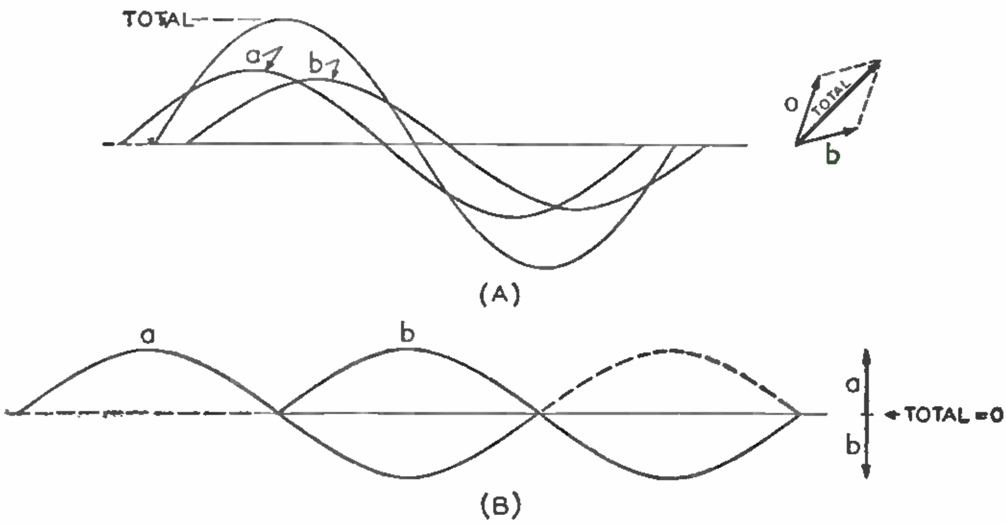


Fig. 1-8. When two harmonic motions of the same frequency, waves a and b, are out of phase by less than 180°, their total is greater than either, as shown by the vector at right of (A). When a and b are 180° out of phase, they cancel as shown in (B).

tone *a* by a certain number of degrees. The vector addition at the right shows how the total amplitude is influenced by the reinforcement of the two tones, causing an addition to the total magnitude over either one by itself. Fig. 1-8(B) illustrates what happens when the same tones of similar frequency are differing in phase by exactly 180°. The vector at the right shows complete cancellation of the total energy, since the tones are now opposing each other resulting in zero amplitude. Keeping this clearly in mind, it is seen that the total amplitude will be larger for smaller angles of phase difference, and if the two tones are exactly in phase, the parallelogram at the right collapses and becomes a straight line that is the sum of the individual amplitudes. As the angle of phase displacement becomes larger, the total amplitude becomes less, until at 180° it becomes zero.

In actual practice, it is realized that under program conditions a large number of different frequencies with varying phase displacements are being covered, and the loudness sensation produced in the ear for a given meter reading is dependent on the number of harmonics present and the phase relationships of these harmonics. It then becomes obvious that acoustical treatment of studios and type of program content will influence the correct interpretation of a volume indicator reading. It is, of course, apparent that the volume indicator performs its duty in respect to showing the magnitude of the waveform, whether it be "distortion peaks," noise, or musical sound, that must be kept within the dynamic range of the transmission system. But when correlating the reading of the volume indicator with the effect produced on the hearing sense of the listener, these problems must be met and analyzed. The loudness sensation for a given meter swing indication has already been discussed in regard to voices of different persons. The same characteristic is noted between individual musical instruments where the number of harmonics and their phase relationships may vary in wide degrees.

Dynamic Range Indication

The volume indicator is used as a means of visually monitoring the magnitude of the program waves for two primary reasons: (a) to compress the original wide dynamic range to an amount consistent with good engineering practice of the broadcast transmission system, and (b) for locating the upper part of the dynamic range below the overload point of associated equipment. For the latter purpose, a scale of 10 db would be adequate; for the former purpose, a much wider decibel range is desirable. Since the instrument is used for both applications, it was decided that a compromise on a scale length of 20 db would be desirable. It appears that as the art and appreciation of higher fidelity service advances, not only the frequency range but also the dynamic range of transmission will be extended, particularly for certain types of program material. This feature becomes a very important one for f-m service. With present-day meters, it is left to the experience and judgment of the operator as to how far the volume should be allowed to drop below the visual indication of the vu meter.

It would appear then that, in the interest of good operating practice, some form of auxiliary monitoring of passages below the present-day meter indication point on types of programs requiring wide dynamic range, might be worth while. A suitable oscilloscope used in conjunction with the meter might be one solution. The practicability of this method would be doubtful due to the fact that the operator's attention must be divided between the monitoring device and the studio action. The same drawback would exist for an indicating meter of such wide scale that the entire meter action does not fall readily into the operator's line of vision. A meter of, say, 270-degree scale would have the same disadvantage of having either the low-passage or maximum-passage indication fall at an awkward position.

Perhaps the most practical solution would be a device consisting essentially of two indicating pointers, one immediately below the other. The lower pointer would indicate the first 50% of channel utilization, with automatic overload protection built into the movement (by limiting tube or network) to prevent overload of this movement when the volume is such that the upper movement is indicating the final 50% of channel utilization. The design should be such that either indicator is in a practical plane of vision for the operator.

Chapter 2

ARE MECHANICAL OPERATIONS APPARENT?

IN THE REALM of the physical, mental, and psychological faculties of the control-room operator lies the success or failure of the broadcaster's daily schedule. A script-writer's masterpiece or a composer's dream can amount to no more than the original worth of his work, plus the ability of the control man to interpret that work on the technical equipment at his command. Yet, perhaps paradoxically, the best qualified operators are the least conspicuous to the listener at home.

An ideal job of switching and blending of microphones for the various performers of a given show is such that the listener-in is entirely unconscious of mechanical operations necessary to their performance. The operator who "cuts" his program at its conclusion, instead of fading out (even though because of time limitations it must be a "quick fade"), not only makes mechanical operations apparent to the listener, but marks himself as a man not entirely a master of his equipment. Exceptions to this rule exist, such as "stunts" of a technical nature that are sometimes aired to impart a technical flavor to the layman. In such programs, technical operations should be accentuated, of course, rather than subdued, but it is well to remember that, as a general rule, the test of the operating technique should be, *"Are mechanical operations apparent?"*

This primary rule should govern the entire operating technique of the control man. Music, speech, or background accompaniment that is too high or too low in level should be gradually adjusted to normal in a manner cognizant of musical and dramatic values. It might appear at first that this prime requisite for good operating practice would conflict seriously with good engineering practice. When levels are too high, overloading of associated equipment at the transmitter occurs. When compression amplifiers are used, as is commonly the case, the distortion arises from excessive compression rather than from overmodulation of the transmitter. It has been proved from extensive tests, however, that distortion caused by momentary overloads simply is not noticeable even to highly trained ears. This appears to be due to physiological and psychological factors that determine the ears' appreciation of aural distortion, resulting in a lack of response to overload distortion occurring at rare intervals and of short duration.

The level of the speaking voice can be least obviously adjusted by correcting the fader setting between words or sentences where slight pauses occur, rather than increasing or decreasing the volume during

PROGRAM TITLE : Musical Clock FOR : Books MEDIUM: ET and Recordings

DATE OF BROADCAST : Thursday Aug.19 FROM : 7:15 am TO: 8:15 am

RECORD OR TRANSCRIPTION

TITLE OF COMPOSITION	BRAND	SERIAL NUMBER	PERFORMING SOC.OR LICENSING AGT.
Got the Moon in My Pocket	W	5163	ASCAP
How About You	Vi	27749	ASCAP
Ferry Boat Serenade	W	3921	ASCAP
Back Home Again in Indiana	De	3786	ASCAP
Blueberry Hill	W	3829	ASCAP
America, I Love You	Co	35865	ASCAP
Chinese Lullaby	W	5690	ASCAP

LEGEND: W - World
Vi - Victor
De - Decca
Co - Columbia
Th - Thesaurus

Fig. 2-1. Typical music sheet for a program of recordings supplied to the announcer operating the turntable and the control-room operator. Brand names enable operator to anticipate volume level.

actual excitation of the microphone by the sound waves. A comparison of these two methods by the operator on his audition channel will reveal the striking difference in the obviousness of level control.

Anticipation can play a major part in smooth level control when circumstances permit. The operator soon becomes familiar with the approximate fader setting of each announcer as he takes over to relieve the preceding announcer. It is obvious here, of course, that ample opportunity is given to adjust the mixer gain before actual air time. This is also possible in some instances with transcribed and recorded shows, when the operator is aware of the brand of recording to be played next.

Fig. 2-1 is a reproduction of a musical sheet for a given program as used at Station WIRE in Indianapolis. The announcer, who operates the turntables, and the operator in the control room each has a copy on hand for reference. It will be noted that the brand of each number, such as World, Victor, Decca, is clearly indicated. This enables the operator to anticipate the level to a certain extent, since, for example, World transcriptions are several vu lower in level than Victor recordings, requiring a higher fader setting. This will also be influenced to a great extent by the type of filter used on the turntable for various recordings, since a different filter is used in many instances for different brands or conditions of recordings and transcriptions. This is discussed more fully in the section on turntable operation appearing at the end of Chapter 4. The gain settings for a given brand will usually be fairly consistent. Thus when the operator has become familiar with the necessary fader adjustment for each brand of transcription or recording, he will be able to use the art of anticipation to good advantage. When the level to be anticipated is uncertain, it is well to remember that from an aesthetic point of view as well as a technical point of view, it is far better to be able to "fade in" the speech or music rather than to experience the shock of excessive volume which must be quickly lowered to normal values.

The foregoing discussion is likely to lead to an erroneous point of view to a newcomer in a control room. It might be well to point out at this time that one of the greatest errors of new men in this field is to "ride gain" to the point of exasperation to a critical listener. The operator should endeavor at all times to give musical and dramatic values a free rein insofar as is practically possible. Remember that from the listener's point of view, the business and purpose of broadcasting is to provide entertainment through the medium of bringing music and dramatics into the home. The technical setup necessary for this purpose has been engineered to a point of perfection; it is only necessary that this equipment be operated in a manner that will promote these musical and dramatic values in their original intent.

The fundamental rule of good operating technique is probably the most abused by innocent operators during the transmission of symphony broadcasts. Suppose that an orchestra of some 40 to 80 members has just finished a number which for the past few minutes has been very pianissimo, say —15 to —20 vu. It is safe to say that the average listener to a symphony program will have his receiver volume adjusted so that comparatively high power exists in the speaker when the studio level hits 0 vu. It is obvious then, what will occur if the announcer suddenly pops in at 0-vu level. The listener may not be actually raised from his chair by this sudden human roar, but the experience, to say the least, is a shock to all five senses, including smell. Sudden crescendos in music are expected, welcomed, and appreciated, but a single announcer, exploiting the glorious qualities of Joe Glotz's Super Zoot Suits at an apparently greater volume than all 80 men with everything in their possession from a piccolo to kettle drums, simply is not only unwelcome, but extremely obnoxious.

It is a safe rule to remember that after such musical numbers as this, the announcer should be held down to about —6 maximum. The difference to be maintained between levels of voice and music will depend not only upon the type of program aired, but also upon the acoustical treatment of the studio and will be mentioned in chapter 3.

The inadequacy of present-day broadcasting to the field of symphony music transmission is quite apparent to most engineers. The discrepancy between the usual 70-db dynamic range of a full orchestra and the actual 30 to 35 db allowed by broadcast equipment is all too obvious to the control man handling such pickups. It has been the practice of some operators who do not appreciate the symphonic form, to bring all low passages up to around —4, then "crank down" on the gain as the orchestra increases its power according to the continuity of the musical score. The fault in this technique should be apparent. If the very lowest passages are brought up to just "jiggle" the meter, and care is taken to use good taste in suppression of the crescendos, a very satisfactory dynamic range may be experienced, since even a range of 25 db will vary the output at the receiving point from 25 milliwatts to nearly 18 watts *on peaks*.

Needless to say the technician on a symphony program, or any musical program, should possess a good ear for music. Rules and regulations will never help a man with a pair of "tin ears" to handle a musical show properly. There are, of course, many competent technicians who do not like or appreciate music, and these men should be assigned to the performance of technical maintenance or transmitter duty. It is nevertheless important that the transmitter technician understand that a great amount of modulation during classical music will be below 20% even with compression line amplifiers.

Recordings and transcriptions of symphony music have already been compressed into broadcast dynamic range, since the recording engineer has essentially the same problem to contend with in relation to this difficulty. Usually all that is necessary for the control technician to do is to set the level on the peaks of the music to correspond with 0 vu or 100 on the scale, and "let it ride."

Specific symphony pickup will be discussed in chapter 11 since this type of program is often handled as a remote program.

Chapter 3

KEEPING SOUND "OUT OF THE MUD"

THE PROBLEM of correlating volume levels with comparative loudness of speech and music has appeared as an item of major importance and should no longer be ignored by broadcast station personnel. Table 1 was compiled as a result of "group tests" of comparative loudness of different types of music with that of speech.[1] The "peak factor" (ratio of peak to rms values) of speech waveform is very great in comparison to that of music waveform, as emphasized by Fig. 3-1. It is apparent, therefore, that 2 to 3 db more power may exist in speech waves in a circuit monitored by an rms meter than is indicated by the meter itself. This will explain the results shown in Table 2, which as well as Table 1, was taken from the aforementioned article. It is apparent then that when speech and music levels are

TABLE 1

Type of Program	Volume Indicator (RMS) Reading for Same Loudness as Speech
Male speech	0
Female speech	0.1
Dance orchestra	2.8
Symphony orchestra	2.7
Male singing	2.0

Showing importance of peaking music 2 to 3 db higher than male speech for equal loudness sensation. (See text.)

adjusted in correct ratio to avoid overloading, the loudness will be approximately the same.

Table 1 contains a discrepancy with the author's personal experience, and is mentioned with the hope of further research and clarification. It will be noticed that results of the tests on this particular group of listeners dictated the need for a 2.8-db higher level for a

[1] Chinn, Gannett, and Morris, "A New Standard Volume Indicator and Reference Level"; *Proceedings*, IRE, January 1940.

dance orchestra, and a 2.7-db higher level for a symphony orchestra over that of male speech. If the author was to compile a similar table of equal loudness from several years experience of watching volume indicators (VI's) on various types of programs, he would choose approximately 3 db higher level for a dance orchestra, and 4 to 6 db higher for a symphony orchestra over that of male speech. The author

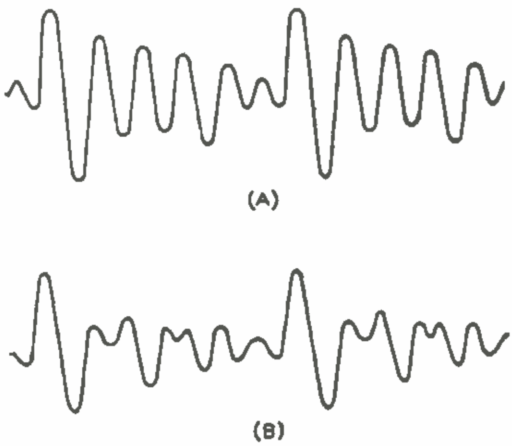


Fig. 3-1. The "peak factor" (ratio of peak to rms values) of music waveform (A) is not as great as the peak factor of voice waveform (B).

feels that this is not caused by a different physical response of the ear itself, but rather to a possible difference of acoustical factors involved, plus the fact that certain psychological factors were not considered in the original tests. By this is meant the important difference in

TABLE 2

Type of Program	No. of Tests	Total No. of Observations	RMS Volume Indicator
Male speech	8	81	22.1
Female speech	8	82	22.8
Piano	5	40	24.1
Brass band	4	25	24.1
Dance orchestra	5	42	24.7
Violin	1	15	25.8
Average speech	16	163	22.4
Average music	15	122	24.5

The final column shows average overload points of different types of programs, measured at the output of a W.E. 94B amplifier. The important fact of this table is the revelation that the point of overload for average speech is about 2 db lower than the point of overload for average music (rms volume indicator).

istening technique between the symphony audience and the dance-nusic listener.

As was mentioned before, because of the nature of the classical type of music, the symphony fan at home will operate his receiver on the average a great deal higher in level than he would for ordinary programs. Five minutes of symphony music will have perhaps 3 to 4 minutes of low to very low levels; the average intensity level over a period of time is far lower than the average intensity level of a dance orchestra in the same time interval. It should then be obvious that a greater difference should exist in the ratio of music to speech levels for symphony programs than for those of dance music. Perhaps if tests were carried out with this difference in receiver volume considered, as well as the type of music on the program, the results would be more nearly in agreement with the foregoing argument.

The acoustical treatment of the studio in which the program originates will affect to a great degree the loudness of voice and music, and in a different ratio. A studio that is overtreated with absorbent material deadens the sound because of high-frequency absorption, and is an outstanding enemy to musical programs. Music from "dead" studios is "down in the mud," lacking in brilliance, and generally dull to hear. The effect on speech, however, is not so pronounced as that on music. Speech originates within a few feet of the microphone and requires much less reverberation to assure naturalness, whereas the space

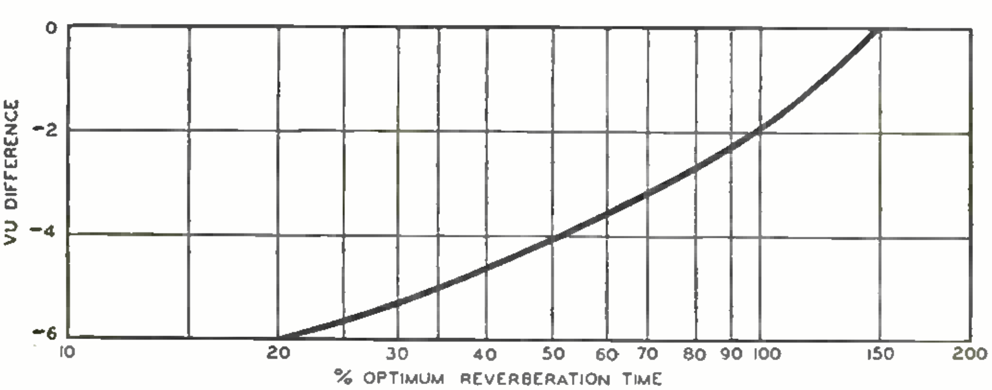


Fig. 3-2. Graph showing the influence of acoustical conditions on ratio of peaking voice and music assuming a necessary 2-db difference for optimum acoustical conditions.

between the source of the music and the microphone is greater, and many things happen to the musical waveforms that must eventually be translated into perceptions of loudness.

Fig. 3-2 is a graph drawn on the assumption of a necessary 2-db difference of voice and music level readings on an rms meter unde normal acoustical conditions. The optimum reverberation time wil vary according to the size of the studio, as shown by the curve of Fig 3-3. The curve of Fig. 3-2 is drawn on a probability basis, correlatin known facts concerning reverberation time with loudness sensation o voice and music. This graph shows the necessity of a lower peakin of voice in relation to music for less reverberation time than normal

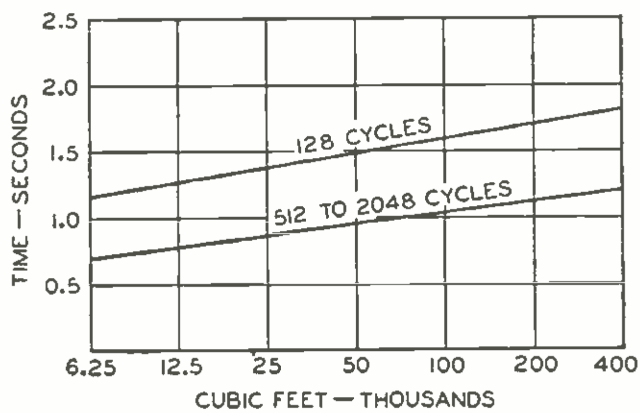


Fig. 3-3. The optimum rever beration time varies with th size of the studio, as is eviden from these curves. See also Fig 3-2.

After Knudsen

and at the same time shows that for 1.5 times the optimum reverbera tion time, where a great amount of reinforcement of the original musi cal waves takes place, the voice and music should be peaked the same

It should be pointed out here that so called "optimum reverberatio time" really is an expression of what constitutes pleasing sound, an this conception is still changing with experience. It may well be tha near future standards of optimum reverberation time will see a con dition which will decidedly alter the above discussion of ratio in peak ing voice and music. The point that is important to keep in mind i that a great majority of present-day studios throughout the countr are below even up-to-date standards of correct reverberation charac teristics; hence the need for the discussion.

The newer "live end, dead-end" studios, with musical instrument placed in the live end and microphones spotted in the dead end, pre sent one solution for properly controlled reverberation. In these stu dios, voice and music peaked at the same level will appear the sam in loudness sensation. In fact, the advancing state of studio develop ment points to all indications that the present day is experiencing a transitional era in which, from some of the most modern studios usin reflecting panels for musical pickups, the brilliance of the music is so great that, when peaked an amount on the meter equal to that o

Courtesy National Broadcasting Co.

Figs. 3-4(A) above, 3-4(B). The live end of a "live-end, dead-end" studio designed to provide properly controlled reverberation. Slanted wooden sound-dispersing panels are suspended against the side walls, forming a series of resonance diaphragms, shown in (A). The walls of this studio are slanted (B) to eliminate standing waves that cause flutter.

TABLE 3

Instrument	Studios of Optimum Reverberation Time, Distance in Feet	Studios of 25% Optimum Reverberation Time, Distance in Feet
Bass viol	6	4
Bass saxophone	6	4–5
Trombone	7	5
Trumpet	12	7
Trumpet (muted)	8	5–6
French horn	8	5
Clarinet	8	5
Flute	6	3–4
Violin	5	3
Piano	15	10
Electric organ	15–20	8–10
Pipe organ	20–25	10–15

voice, the voices sound much lower in loudness than the music. This brings to mind again the importance of using judgment in aural perspective when "riding gain" on productions with the intent of achieving a properly balanced effect in the listener's home.

The use of wood in broadcasting in accordance with exact acoustical specifications for controlled reverberation was apparently introduced by CBS in New York about 1935. The entire "live end" of the studio was constructed as a series of resonance diaphragms of seasoned wood held in suspension with air chambers behind them, as shown in Fig. 3-4(A). The wood panels that cover about one-third of the side walls are placed on slanted surfaces so that the side walls form shallow "V's" running from ceiling to floor. These are so placed that the wall surfaces are not parallel to one another, as shown in Fig. 3-4(B). This eliminates standing waves which would normally produce "flutter." However, because of the highly reflective surfaces of the wood, a certain amount of reverberation is achieved, a quality which adds life and brilliance to the speech and music originating in this type studio.

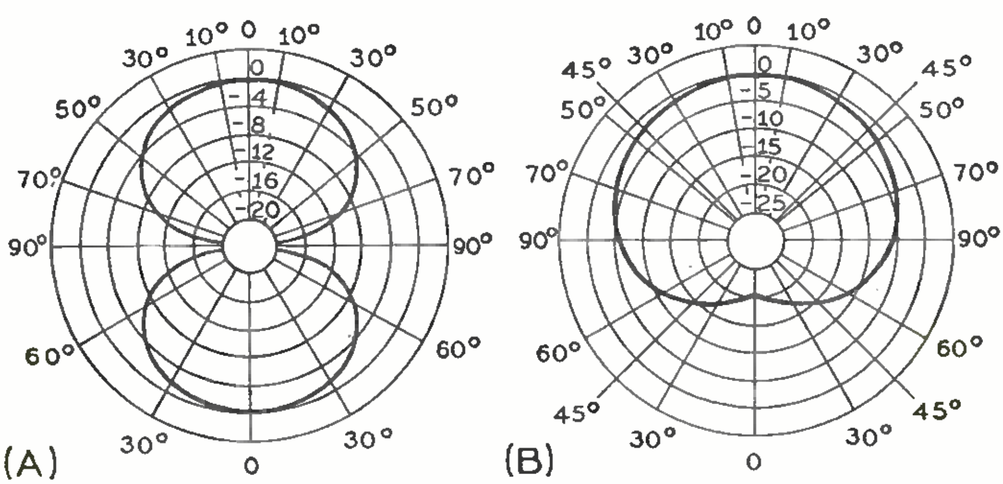
This is essentially the same principal used by WBBM (CBS) in Chicago and other key points, as well as by the other major networks in their key stations. A number of smaller independent stations have since utilized this type of construction in their studios, and it is hoped that others who contemplate new studios or remodeling of old ones will recognize the tremendous importance of a degree of liveness in broadcast studios.

Chapter 4

YOU'RE OFTEN A PRODUCER TOO

THE OPERATOR of the control room is called upon many times to set up complex musical and dramatic shows. This is especially true in smaller stations that have no production man, and is sometimes true of important key network stations where the control man must achieve the desired results of the production man assigned to a particular show. The responsibility of setups of studio shows is not a simple one. Many years of research and much thought have gone into production, and a knowledge of at least the fundamentals of the art, as they affect the technical duties, will help the control technician over many difficult situations that will arise in the course of his work.

In determining the proper use and placement of microphones for any given setup, it is important that the operator becomes familiar with the pickup patterns of the microphones used. These patterns illustrate completely the function as to amplitude and frequency response for varying degrees of placement about the face of the microphone. Fig. 4-1(A) shows the pattern of the RCA 44-BX velocity microphone, and Fig. 4-1(B) is the pattern of a RCA 77-B combina-



Courtesy RCA Mfg. Co.

Fig. 4-1. The pickup response pattern of the ribbon or velocity microphone (A) is bidirectional and that of the combination ribbon and pressure type (B) is unidirectional.

tion ribbon and pressure type instrument. There are several important points of interest relating to these patterns which show great differences in characteristics aside from the most apparent one, that of bidirectional and unidirectional pickup.

An analysis of the patterns reveals a much wider range of amplitude response for the combination pressure gradient (ribbon) and pressure type microphone [Fig. 4-1(B)] than for the ribbon type alone. See Fig. 4-2. Take for example the 1000-cycle curve for the 44-BX ve-

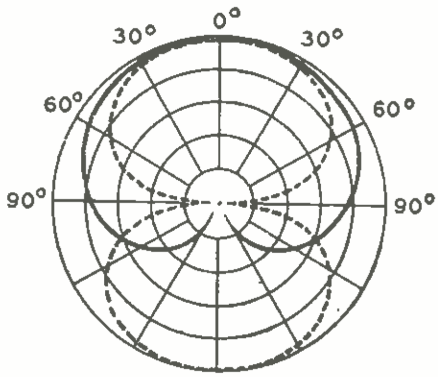


Fig. 4-2. The amplitude response of the 77B combination type microphone (solid curve) has a wider range than the 44BX velocity microphone (dotted curve). Such patterns are useful for making setups and eliminating unwanted sounds.

locity microphone. It is noted from Fig. 4-1(A) that at an angle of 70 degrees, the amplitude response is down about 10 db in respect to its response at a given distance at 0 degrees. Now note on the 1000-cycle response curve of the 77-B combination type in Fig. 4-1(B) that the amplitude response at 70 degrees is down only approximately 3 db from 0 degrees reference. These patterns are useful for determining the setups necessary for discriminating against unwanted sources of sound, and for obtaining a particular relation between sounds of different sources. It can be seen that as a performer is moved around the microphone, loss of sensitivity may be compensated for by moving closer to the instrument.

It is clear then that characteristics of the type or types of microphone in use should be thoroughly understood. Fig. 4-2 is presented as a basic principal in using patterns of a unidirectional microphone of the combination ribbon and pressure type. It is a well-known fact that, because of the pressure gradient characteristic of the ribbon microphone, the instrument will favor the lower frequencies of longer wavelength under close talking conditions. For this reason announcers on such microphones must be at least 1.5 to 2 feet from the microphone. When close talking becomes necessary, however, the combination type instrument may be utilized by the engineer, who can then safely instruct the announcer to approach an angle of 90 degrees with the face of the microphone as shown in Fig. 4-3, and work as closely as desired. In this position the ribbon element will contribute practically no energy to the output, leaving the pickup to the pressure element, which is not affected by the spherical character of close talking sound waves.

It may be seen that the "fading zone," where sensitivity falls off rapidly for increasing angles, is just as useful as the ordinary pickup zone, since the quality is just as good and a fine degree of shading may be realized by understanding its proper use.

As will be described and illustrated in the technical explanation of microphones in Part 6, a number of modern ribbon and combination microphones have an associated equalizing feature known as a "speech strap." In the "speech" position, close talking into the ribbon element will not result in excessive bass response. When the same microphone, however, is used both for the musical pickup and the announcer, the strap is placed in the "music" position, and the announcer must work the mike as explained above.

As far as is practically possible, only one microphone should be used for a given pickup. When two or more instruments are used, serious frequency and delay distortion is likely to result, since each

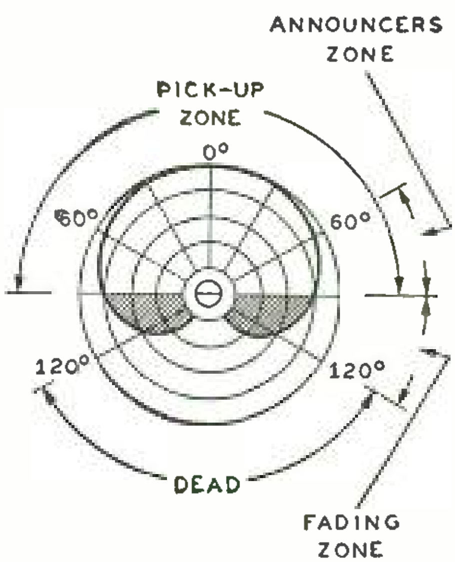


Fig. 4-3. When close talking into the combination type microphone is necessary, it can be approached as closely as desired in the zone between 60 and 90 degrees. The lower response of the "fading" zone between 90 and 120 degrees, does not affect the quality.

Courtesy Western Electric Co.

microphone will be a different distance from a given sound source. It can be seen that sound waves would not reach the instruments at the same time, and their combined outputs will result in partial reinforcements or cancellation, depending on their phase relationship.

When it is absolutely necessary to use two microphones very close together, they may be poled so that their outputs are additive rather than subtractive, either by rotating a bidirectional microphone through 180 degrees, or by reversing the connections on a unidirectional microphone when the outputs are subtractive. This may be accomplished by using a patchcord between any two terminations of the circuit on the jack panel, and reversing *one* end at a time during the test. The proper phasing of the two instruments is accomplished by watching the vu indicator when the two inputs are switched to the first one, then both together, and noting whether the combined outputs are additive or subtractive. Usually one connection will give greater additive effect than the other connection, and this effect some-

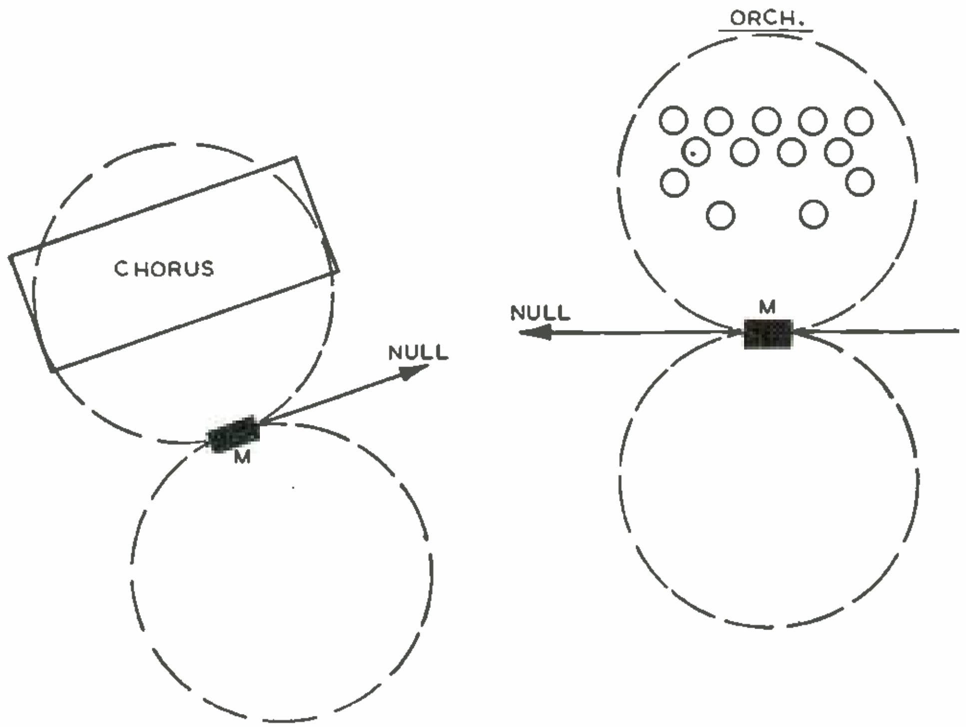


Fig. 4-4. A good basic arrangement of ribbon type microphones, M, for proper pickup of sounds from two sources. The dotted circles indicate the microphones' response areas.

times changes with a change of frequency; although for complex waves where we are not concerned with pure tones of a single frequency, a good average additive effect can be obtained. Fig. 4-4 shows the basic idea in proper placement of microphones when two are necessary for proper pickup of two separate sound sources.

As a rule, the most common error of newcomers to control rooms is the placement of the microphone too close to the sound source. As has been discussed before, loudness sensation for a given meter reading depends largely on the harmonic content of the waveform. Placement of the microphone extremely close to the musical instruments results in peaks on the vu meter that are almost inaudible to the listener, and since the intensity of these peaks must be kept below 0 vu, the resultant music is completely "down in the mud" and lacking in brilliance. Smooth control under these conditions is impossible, and harmonic content is very low.

For pickup of piano music, a distance of at least 15 feet between microphone and piano should be observed in studios of optimum reverberation time. More intimate pickups are necessary for dead studios, since no reinforcement of the sound waves takes place. Too great distance in such studios results in a thin sound, lacking in body.

For the purpose of presenting a basic rule for distance in microphone placement for certain instrumental solos, Table 3 is presented. This table is not meant to be an infallible rule of exact distances in microphone placement. It is intended to convey an idea of the minimum distance to start from on rehearsals before air time. Any change to be made then would be toward greater distances rather than less. It is imperative, of course, that the operator experiment with microphone placement in his own studios to get the best results from its particular acoustical condition.

The effect of phase shift in studios on the quality of musical sounds is important even though the human ear is not essentially a "form

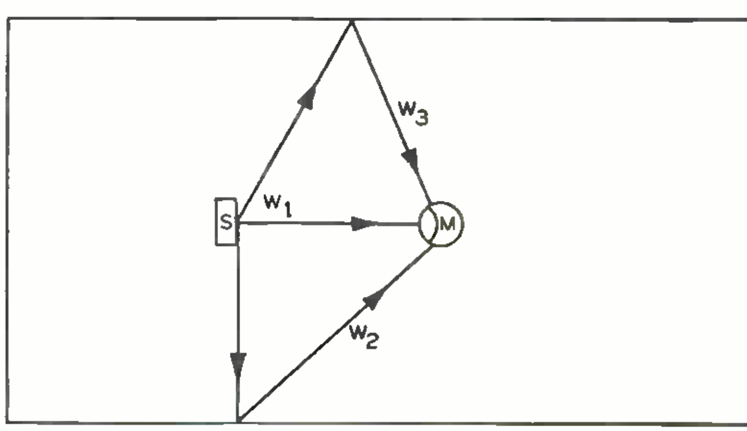


Fig. 4-5. The energy arriving at the microphone M is the sum of the initial energy W_1 of the direct sound from the source S together with the reflected wave trains W_2 and W_3.

analyzer." Phase shift causes trouble in both live and dead studios. "Dead spots" nearly always exist in studios because of cancellation of large amounts of the complex wave frequencies caused by phase shift. Fig. 4-5 illustrates the basic theory of wave-train travel from its source to the microphone spot. The energy at *M*, the microphone, is the energy of the initial direct wave train W_1 from the sources, plus the energy of the reflected wave trains W_2 and W_3. The amount of energy of the reflected waves is governed by the characteristics of the reflecting surface, which in turn determines the reverberation time of the studio. It may be observed here how phase shift, because of the different distances over which the waves travel, could cause reinforcement or cancellation of certain frequencies at the microphone spot.

Complete dead spots are more likely to occur in live studios, since reflection from a perfectly hard surface causes no change in phase of the individual frequencies of the complex wave, creating a condition in which, theoretically, complete cancellation of the entire spectrum at a particular spot in the studio might occur. In dead studios, absorption of the higher frequencies is greater than at lower frequencies, thus making complete cancellation of the complex wave unlikely.

If this phenomenon is fully understood, it will be realized that microphone placement is much more critical in dead than in live studios, since dead spots are easily avoided in live-end studios where reinforcement of the musical tones is smooth and even over the entire spectrum of frequencies for a given microphone spot; whereas the placement is only a compromise of the greatest possible frequency range for a given pickup spot in dead studios. Construction of the new live-end studios with sidewalls arranged in "V's" so that no surface is parallel, results in a dispersion of sound that helps to overcome the occurrence of dead spots in this type of studio. The contribution of the reflected waves in a live-end studio to the loudness intensity, resulting from the reinforcement and sustaining of the overtones of the musical instruments, gives these studios a decided advantage over the older type "general purpose" studios.

Importance of Rehearsals

The co-ordination of hand, ear, sight, and sound for the purpose of blending the component parts of a studio performance is best gained by the operator through the medium of rehearsals. Fading in or out of various microphones, turning them off and on, is the procedure which enables the engineer to play upon the sound of voice and orchestra much as if the control panel itself were a musical instrument. Indeed, in a sense, this is just what it is. The ratio of fader adjustments will determine the apparent distance of a singer from the audience; the voice may be smothered with music or may be made to stand alone with only a suggestion of background accompaniment. A proper blend of voice and music, or of dramatics and sound effects, can only be properly created through careful and detailed rehearsals. This is the one and only method of preventing the "on air" show from becoming only a caricature of the original idea.

Many "old timers" are familiar with the coloratura soprano who is nicely "adjusted" on rehearsal, then hits +20 vu on the air without batting an eyelash. This condition simply emphasizes one important point: the operator must be apt at diplomacy as well as technically conscious. Talent *must* be made cognizant of the importance of treating rehearsals just the same as "on air" performances. If the performers are instructed in "mike technique" from the point of view of making *their* performance sound just the way *they* desire to the listener, the operator will find ready and willing co-operation. Do not be shy of temperament. The more temperamental the performer, the more he likes to be "fussed over" at rehearsals to gain emphasis of his best talents. Ask any operator or producer of big time shows out of New York, Hollywood, or Chicago; they are in a position to know.

The distance to be maintained between vocalist and microphone will depend on the type or style of vocal form used by the singer. In general there are two commonly encountered types of vocalists, the "crooner" and the "operatic" singer. Whereas the crooner will employ a dynamic range of around 15 vu, the "operatic" singer will use a much wider dynamic range. For the former type, where the sound waves are garnered principally from activation of the upper larynx and throat muscles with comparatively low-pressure waves resulting, it is usually necessary to work close to very close into the microphone. The vocalist who "sings out" by bringing the chest muscles into action must be placed a minimum of 4 feet, preferably 6 to 8 feet, from the microphone. This may appear to be an excessive distance, but actually a much greater dynamic range and brilliancy of voice may be realized by using this distance for singers who range from extremely low to very high air pressures to excite the microphone element. There are of course a number of "in between" singers, such as some of those who sing with dance orchestras, and they are usually placed from 2 to 3 feet from the microphone.

Microphone technique for actors in a dramatic program spells success or failure in creating the desired illusion in the loudspeaker. Usually one microphone only is used for the entire cast, with a separate microphone for sound effects. As each actor plays his part, he steps up to the microphone, sometimes approaching from the fading zone into the announce zone to create the illusion of approaching the scene of action, sometimes leaving in the same manner. In some cases "board fades" are marked on the script [Fig. 4-5(A)]. The operator fades the entire studio setup including sound effects by fading out with the "master gain" control. Shouts or screams must be performed in the shading area "off mike" to avoid excessive pressure on the microphone element which would require an excessive gain adjustment by the operator, losing the effectiveness of the illusion.

While studio rehearsals are in progress, it is imperative that the engineer and production director be able to talk to the cast for the purpose of instruction in positions, microphone technique, etc. This is accomplished by means of a "talk-back," which consists of a microphone in the control room connected to an amplifier feeding a loud-

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1.  OPENING SOUND.  SOMBER, DRAMATIC STRAINS      (ORCHESTRA)
2.  NARRATOR.   (LOW MONOTONE, VERY CLOSE TO MIKE).  Have you ever been
3.              to Hell?... Well I have ... and now I have to go back...
4.              to stay!
5.  SOUND.  MUSICAL CRESCENDO - THEN SILENCE FOR 3 SECONDS...
6.  NARRATOR.   She had everything a man could want, topped off with
7.              a beautiful name ... Clarissa.  I'll never forget
8.              that first night I saw her, it was raining... as it
9.              had been for hours... and..
10. SOUND.  FADE IN RAIN ON PAVEMENT.  STREET NOISES..AUTO HORNS.
11.         CAR SWIFTLY PASSING..SPLASHING WATER..
12. CLARISSA.   (STARTLED) (OFF MIKE)  Oh!
13. NARRATOR.   Oh Miss!  That's a tough break... Better get back here..
14.             farther from the curb.. motorists don't think you know.
15.             Here..share my umbrella.
16. CLARISSA.   (DRY LAUGH).  I'm afraid I shan't get any wetter now..
17.             Thank you anyway.  (PAUSE)  My name's Clarissa, what's
18.             yours?  (START BOARD FADE HERE)  3 SECOND PAUSE.
19. NARRATOR.   (REMINISCENTLY).  Just like that... and she was young..
20.             and so sweet... and beautiful!
```

Board Fade

Fig. 4-5(A). Sample of script which an engineer has marked so that he can "cue" himself for what is coming. The "board fade" is done by fading the master gain control. Note that in line 10 the "fade in" might be done by the turntable operator if sound is on records; if rain and street sounds originate in studio, control man fades in associated microphone.

speaker in the studio. Switches on the control console and perhaps also on the production director's console where such is used, are provided for the talk-back mike. The control man is sometimes provided with a foot-switch to free his hands for the controls. When this mike is turned on, the control-room speaker is cut off by a relay interlocked

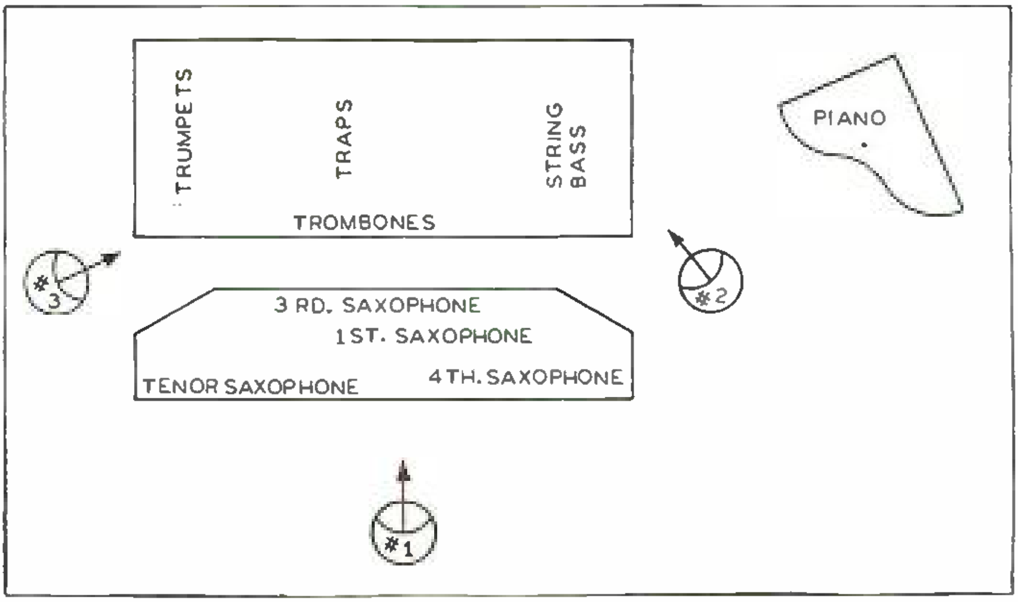


Fig. 4-6. Microphone arrangement for musical show often necessary in a "dead" studio.

with the switch to prevent acoustic feedback. This microphone is also electrically interlocked with the "on-air" position of the output switch so that it may not be operated during the time a show is actually being broadcast.

Musical Setups

Figs. 4-6 and 4-7 illustrate specific setups for musical shows. Acoustical conditions are so varied that no specific rules can be drawn up for instrumental placement about the microphones. The most important rule is to be thoroughly familiar with the pickup patterns of the microphones used, as outlined previously. One microphone is to be preferred in a sufficiently live studio for a complete musical aggregation, whereas dead studios requiring more intricate pickups, may require two or more microphones to cover all the musical instruments.

Network practice in the pickup of twin pianos is illustrated in Fig. 4-8. The lids of the pianos are removed and the microphone raised slightly higher than for single-piano setups. When an audience is pres-

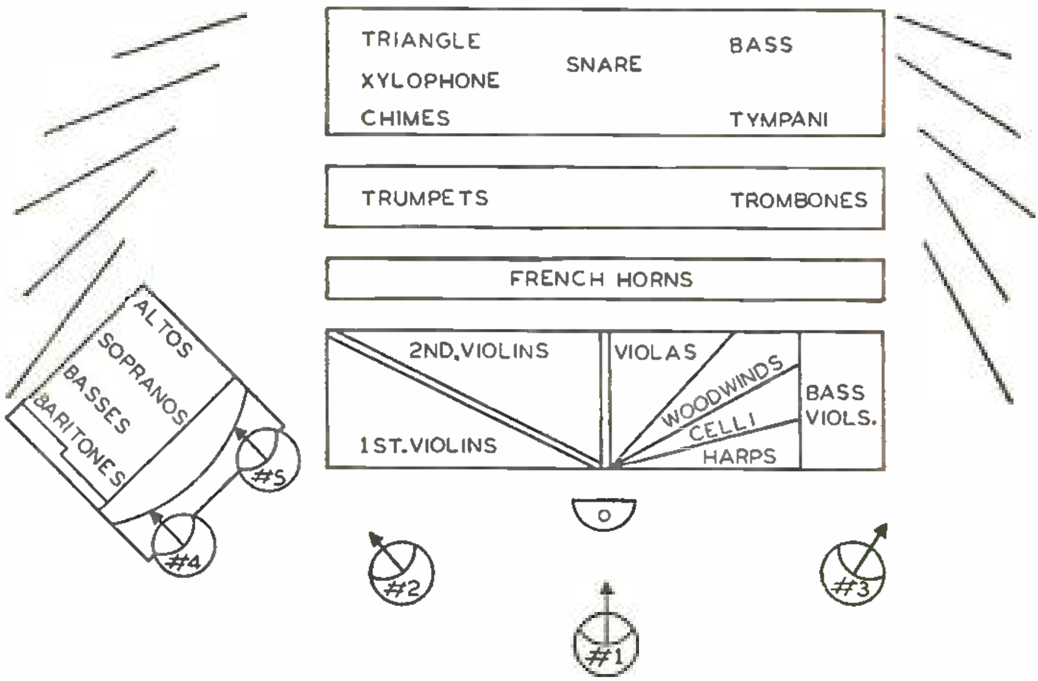


Fig. 4-7. Orchestra and choral arrangement for a "live" studio, mike 1 for main orchestra; mike 2, soloist; 3, announcer; 4 and 5 for choir, when clarity of diction is needed. Mike 2 used for over-all choral effect.

ent in a studio, "applause" and "laugh" mikes are swung out over the audience on booms or suspended from the ceiling so that the "presence" of the audience may be "boosted" in gain by the control engineer when necessary.

When obtaining a check on the "balance" of the various instruments on a musical program, the monitor speaker volume in the control room should not be run at excessively high levels. There is a tendency on the part of many control men to run their monitor speakers at

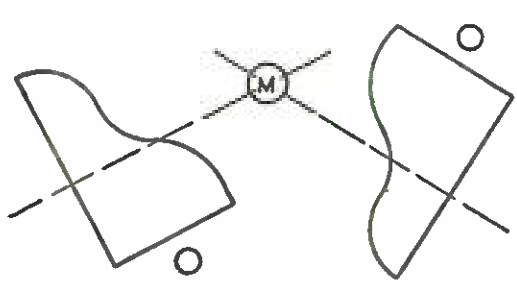


Fig. 4-8. A microphone M for a two-piano pickup is placed between and slightly higher than the pianos from which the lids have been removed.

levels that are almost never maintained in the home. Fig. 4-9 illustrates the relative response of the "average" ear to different frequencies at a given level. It may be observed that the threshold of hearing at 32 cycles is 60 db, whereas for a frequency of approximately

2500 cycles the threshold of hearing starts at about —8 db. When control-room speakers are run at excessive levels, bass response is much greater than it would be at normal levels, which is likely to result in the placement of the bass instruments in a lower sensitivity area of the microphone. When this occurs, bass response is almost

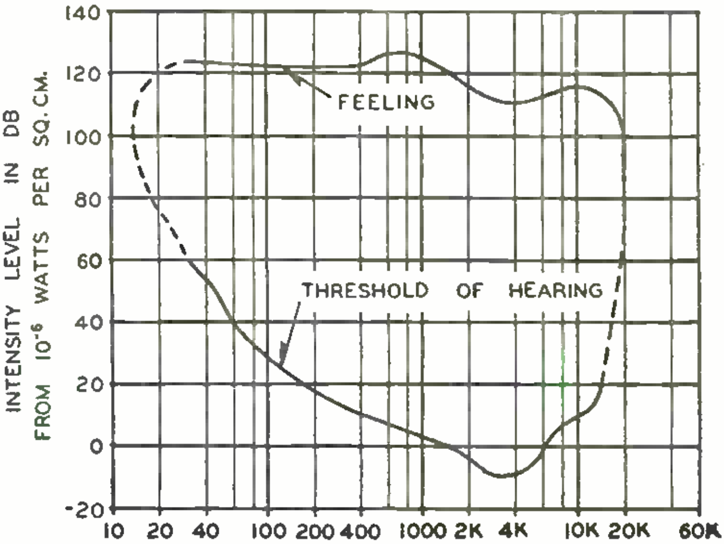
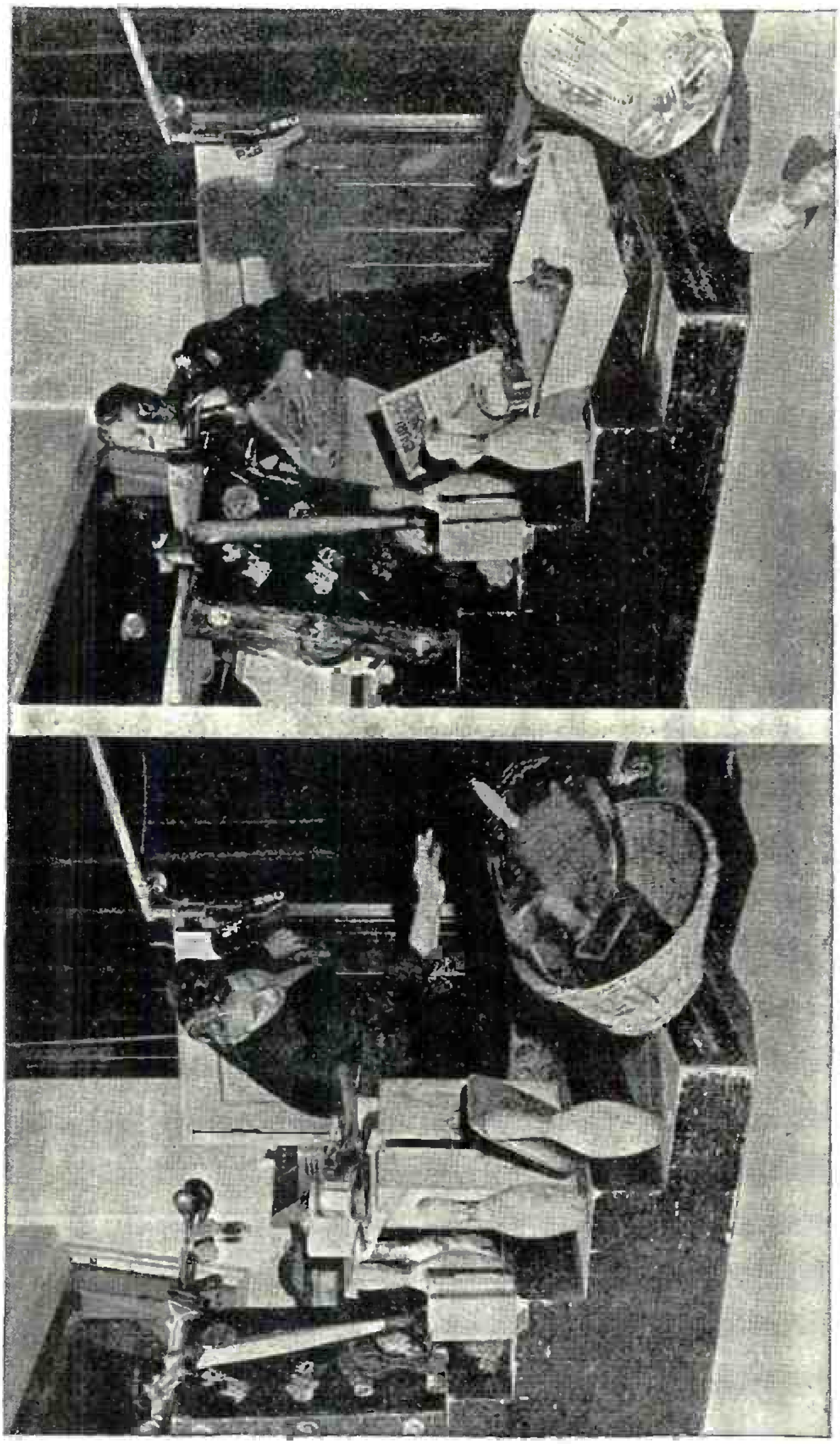


Fig. 4-9. The lower curve shows how the average human ear responds relatively to different frequencies at a given level. Note that the higher frequencies affect the ear to a lesser degree than the bass or lower frequencies.

inaudible in the receiver at home. This characteristic of the human ear has resulted in the development of the "bass boost" circuit in modern receivers which is intended to accentuate the bass response in receivers operating at low levels.

Sound Effects

Major network practices in the art of sound effects has developed over the years into one of the most highly specialized fields of broadcasting. A sound effects technician can take the lowly strawberry box and create illusions ranging from the squeak of a wooden gate or the squeak of a ship moored to a dock, to the terrible rending crashes and splintering of wood for collisions of any description. A bow of a bass viol is drawn in a particular manner over the edges of the box for the first effects, while the box is crumbled between the hands close to the microphone for the collision effect. Rainfall is simulated by the pouring of birdseed or buckshot on a sheet of parchment or by a rain machine, consisting of perforated pipes through which water pours onto brushes in a tub, as shown in Fig. 4-10. Of course, actual objects are also used to produce certain sound effects as illustrated in Figs. 4-11(A) and (B), which show the contents falling out of Fibber McGee's famous closet on the NBC "Fibber McGee and Molly" program.

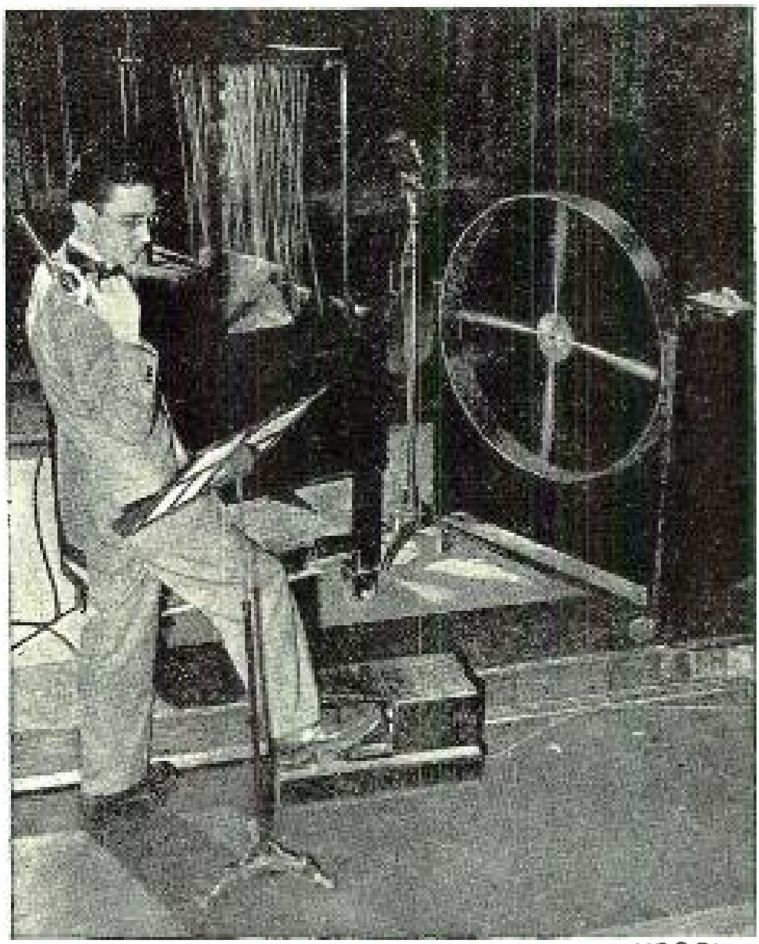


NBC Photos

Fig. 4-11(A), left, (B). When the door of the famous closet of the "Fibber McGee and Molly" program is opened by the operator (A), he starts the noise by pushing the clothes basket and its contents off the lower step. In (B) he is shown just before shoving the rest of the din-making items off the upper steps, the noise being picked up by the microphone suspended at the right.

BB shot rolled back and forth with skillful timing over a copper screen can simulate either a lazy palm-bordered beach or a veritable turmoil of angry waves in an ocean storm. Cellophane crackled gently between the hands close to the microphone can create the illusion of the most terrible forest fire imaginable.

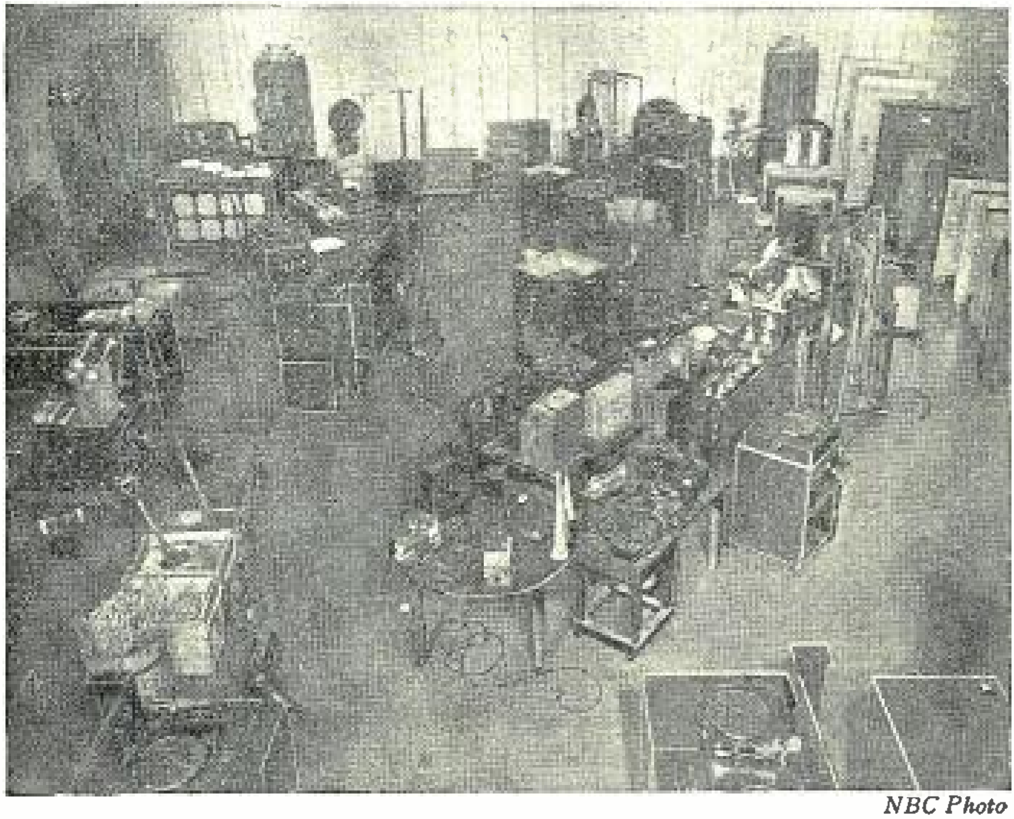
The sound technicians' heterogeneous collection as shown in Fig. 4-12, consists of all sorts of weird machines, hail and wind machines, boxes in which glass is shattered, thunder drums, hurricane machines,



NBC Photo

Fig. 4-10. Sound effects for a good night for a murder. The noise of the howling wind comes from the electrically revolved reeds in the circular shield at the right, controlled by the operator's foot, and the heavy rainstorm results from the rain machine on the left, being turned on full force.

heavy doors on frames, keys, and a thousand items entirely beyond the scope of this book to reveal. In addition he has a console on which a number of turntables are mounted with their individual pickup arms and dials which automatically "count" the number of grooves set in from the edge for proper "cuing" sound effects. These turntables may be varied from 0 to about 150 rpm to make still more flexible the number of weird and uncanny effects that can be obtained from recordings.



NBC Photo

Fig. 4-12. The sound equipment storage room in the Chicago studios of the National Broadcasting Co.

The voice can be made to sound as though it were coming over a telephone by means of a "filter mike," which is simply a microphone run through a filter amplifier, clipping high and low frequencies so that the quality is similar to that heard in the telephone receiver. Reverberation may be added by feeding the signal to be so treated into

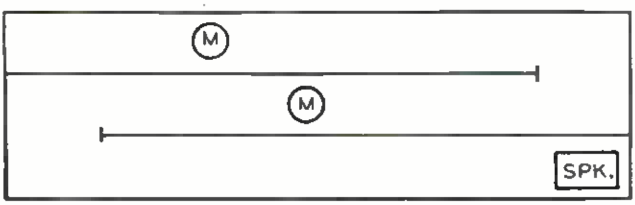


Fig. 4-13. The further a microphone is placed from the speaker in a "reverberation chamber," the larger seems the hall or cavern in which the action occurs.

a speaker at one end of a "reverberation chamber" as illustrated in Fig. 4-13. The farther away the microphone is placed, the larger becomes the hall or cavern meant to be simulated in the drama. The illusion of talking in close quarters such as that of a telephone booth is created by placing a microphone in a sound absorbent booth, as shown in Fig. 4-14.

Although the average broadcast station is much more limited in elaborate equipment utilized by the major network key stations, there

Fig. 4-14. When a microphone is placed in a booth with walls lined with sound-absorbent material, the resulting speech seems to be coming from a telephone booth.

is no limit to the possibilities of using what equipment is available to the ingenious technician. A good telephone effect can be achieved by feeding a microphone signal through a separate amplifier and exciting a pair of cheap headphones (the cheaper, the better) that may

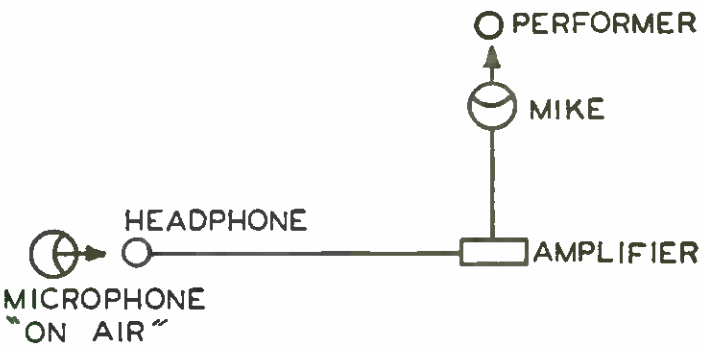


Fig. 4-15. Conversation over a telephone can also be simulated by feeding the amplified output of one microphone into headphones and broadcasting their sound.

be held immediately adjacent to another microphone in the studio. This circuit is illustrated schematically in Fig. 4-15.

A slight reverberation effect may be obtained by placing a microphone immediately above the sounding board holes of a piano, and directing the voice by means of a megaphone or tube over the strings of the piano. The sustaining pedal is held down to allow the strings to vibrate freely when the voice waves are impinged upon them.

Several good textbooks exist on sound effects and will provide more detailed information.

Importance of Control-Room Maintenance

There is no time allowed in a broadcaster's daily schedule for trouble in equipment. There is no allowance made by advertising agencies and producers for bad quality of a studio show due to weak tubes, faulty patch-cords, dirty jacks, or fader controls. Complete failure of equipment is apt to occur in even the best maintained control room due to a defective tube or power supply failure, but when all is simmered down to actual fact, there is *never* an excuse for fuzzy sounds or any kinds of distortion arising from dirt collected in jack strips or on contacts of fader controls. A detailed, well-performed maintenance schedule is mandatory to trouble-free operation.

All tubes should be checked at regular intervals, preferably once a month. Weak and questionable tubes should be immediately replaced. Visual inspection of all rectifier tubes should be made every morning before sign-on, and any such tube showing an undue amount of blue glow should be replaced. Jacks, since they constitute both series and parallel connections in the path of the signal, must be kept free of dust and dirt. They should be frequently vacuum cleaned, and the jack contacts kept clean by regular insertions and removals of patch-cord plugs. The outside cover of fader controls should be removed about once a week and the contacts cleaned with a small brush and carbon tetrachloride. A very thin coating of white vaseline after this cleaning helps to prevent wear. All relay contacts in the installation should be regularly cleaned with crocus cloth or strip of glazed paper. Smooth trouble-free operation of control-room equipment rests largely on this maintenance schedule and the technicians responsible for carrying it out to the letter. (A detailed discussion of preventive maintenance will be found in Part 5.)

Transcription Turntables

The practice of playing recordings and transcriptions varies considerably with different stations. In many of the smaller stations, the control man operates the turntables as well as running the control console. In the majority of the stations of 5 kw or more, either the announcer runs the tables, or an especially trained person is used to run the turntables, which may be in a separate room just for this purpose, as shown in Fig. 4-16.

Recorded and transcribed shows constitute a most important part of a broadcaster's daily schedule. "Transcriptions" are recordings made especially for broadcasting purposes; they are usually 16 inches in diameter and use a turntable speed of 33⅓ rpm to enable recording a full 15 minutes of program time.

WOR Photo

Fig. 4-16. The transcription studio at Station WOR, New York.

A transcription "platter" may also consist of a number of separate musical or voice selections on a single disk, in which case they are numbered on the label with the titles of each number listed. Also on this label will be the information as to lateral or vertical cut, start on inside or outside groove, and reproduction speed (33⅓ or 78 rpm). This is enough to keep any operator "on his toes," especially when a program consists of both recordings and transcriptions which may require change of turntable speed, lateral or vertical switch placement, and noting whether the cut is started on the inside or outside groove.

Then too, a filter selector switch is employed to select a suitable frequency compensation for the particular disk used. For example, RCA lists typical switch positions for the 70-CI turntable as follows:

Lateral

#1. Transcriptions, Orthacoustic, Columbia.

#2. Home records and worn transcriptions.

#3. Home records, World, Decca, and AMP.
#4. Test records and special recordings (wide open at highs).

Vertical

#1. World and AMP transcriptions.
#2. Worn transcriptions.

All records, and some transcriptions, are played at 78 rpm (same as the record player at home), are "laterally" cut, and played from outside groove toward the inside. Most transcriptions, however, play at 33⅓ rpm. In addition to this, some transcriptions are cut "vertically," that is, the groove variations that comprise the signal are varied up and down instead of side to side, using the depth on the coating of the disk. Also, some of them play from inside-out, and require the starting of the pickup arm on the inside groove.

Turntable Operation

In operating a turntable, it is necessary to be sure that the pickup selector switch is on the proper setting for the pickup arm used (lateral or vertical); that the turntable speed switch is on the correct speed adjustment for the particular recording used (33⅓ or 78 rpm), and that the disk has been properly "cued." This means that the pickup arm must be at the spot on the groove where the announcement or music begins, so that no time is lost in waiting for the arm to reach that point on the disk. This is usually accomplished by using headphones on an auxiliary amplifier so that each disk may be "cued in" preparatory to going on the air.

When the disk has been properly "cued in," most experienced operators find it advantageous to start the turntable moving while holding the disk (on the outside edge so as not to touch the grooves) to keep it from turning until start is desired. This practice eliminates "wows" that are apt to occur on the starting due to time taken for the turntable to gain proper running speed. When this trick of operation is not followed, the disk should be "cued back" at least one full revolution of the turntable so that the proper speed will be reached before start of the signal.

The art of smooth turntable operation on the air takes considerable practice by the operator. Familiarity with the operating procedure can be gained only by practice, and most stations demand a thorough "break in" training before entrusting the operator with an air show comprised of recordings and transcriptions.

The music library of a broadcast station may contain files of thousands of recordings and transcriptions, and their proper care in storing and handling is an important factor in "on the air" quality of reproduction. Excessive heat and dust in the air are major enemies to be considered in the storage room. The library should be well air-conditioned, with an efficient dust-filtering system. In any case, the disk should be cleaned with a soft dry cloth before playing. Static electricity causes dust to cling tightly to records, and all precautions such as use of linoleum floors in library and turntable room to reduce static electricity should be taken. Finger marks cause noisy reproduction due to the oil and grease from the hands causing foreign matter to cling close to the walls of the grooves. Platters should be handled on the edge only.

For this same reason, the permanent type pickup needle should not be "swiped-off" with the fingers in an attempt to clear it of dust. A small soft brush should be used.

Instantaneous Recording Department

All large stations, and many of the smaller stations have a recording department where acetate-coated disks may be cut for immediate playback if necessary. Such equipment is used for recording programs such as delayed broadcasts, rehearsals, auditions, or the reference file. A reference file is kept by some large stations of the entire broadcast day, or of portions thereof. The art of recording, including equipment and stylus adjustment, is a complex field of its own, and an entire textbook is necessary to do it justice. There are several good manuals of recording technique published today, and any technician who may be concerned with this department of a broadcast station should obtain and study them.

The Influence of F.M.

The influence of f.m. (frequency modulation) on future operational practices is not to be denied, whether or not f.m. will ever entirely replace or simply supplement the present a-m stations is indeed an abstruse problem. However, it is a certainty that this new type of service, with static-free reception, greater frequency and dynamic range, and freedom from interchannel interference, will find a highly important niche in the future of radiobroadcasting. It is entirely possible that local and shared-channel broadcast stations will gradually transfer to f.m. for the purpose of providing better interference-free coverage both night and day for its primary area.

The great difference in dynamic range between a.m. and f.m. will undoubtedly call for new types of visual indicators in level and a slightly new technique in general operating practice. It is hoped by the author that as the art of f.m. advances, the new technique can be analyzed and presented in a possible future edition of this handbook. The complex operating practices in relation to television will also be included as the state of the art advances and operating standards are more definitely stabilized.

Chapter 5

PUT THAT MIKE THERE!

By Bert H. Koeblitz

The problem of studio pickups or setups is a little difficult to approach because conditions vary so widely between one station and another. In a small local station, the technician may have full control of what goes where and why; whereas in a network center the technician may find himself surrounded by a superabundance of production men to take care of this. In the first case, knowledge is essential to success. In the latter instance the technician can be of real help to the production man. Production men, unless they have been recruited from the technical department, rarely know anything about microphone patterns. Instead, they pursue a series of superstitions and grandma's tales about what a certain type of microphone will or will not do. Therefore a technician with thorough knowledge can help the production man over many difficult spots, and in the case of important programs, frequently finds himself the recipient of slight remembrances now and then.

But that is only one conditional variation. Another is studio construction. What may be good practice at one station may not do at all somewhere else. To describe a specific setup at WHK or anywhere else would accomplish little of value. The important thing is that the same fundamentals can be used to determine whether a given practice is good or bad in your own particular studios. However, certain specific examples will be given, not to demonstrate what is done at WHK, but to illustrate principles which can be applied in any station.

Large Orchestra

The first program which comes to mind is one involving about as many things at one time as will ever be encountered outside a network center. It is a so-called "variety" program, although "hodgepodge" would be far more accurate. It consists of a 25-piece orchestra which is really ten miscellaneous additions to a 15-piece dance band which in its turn further degenerates into a "gut bucket" four. Then there is a 20-voice chorus, a drama cast, a novelty group, a guest artist, a master of ceremonies, and an announcer. Before the program went on the air, the production man tried the orchestra in a straight section-in-front-of-section style, sections side by side, sections in little "V" formations, lengthwise, sideways, and diagonally in the studio, but to no avail. He knew what he wanted *but he did not know how to get it.* The problem was turned over to the technician, who eventually straightened things out. That illustrates fundamental No. 1: be prepared with a full knowledge of what can be done in *your* studios with *your* microphones.

The setup finally used for the orchestra was the section-in-front-of-section type. The section nearest the microphone consisted of four violins and two violas. Between them and the saxophone section were a cello and harp. Brass was in the last section with the trombone in front of the trumpets. The trumpets were put on high risers and the trombones on low risers, not for setup purposes but so the men could see the director without difficulty. Piano, drums, bass, and guitar were placed so they could hear each other.

Now let's go back to the perspiring production man for a moment. He failed to get a satisfactory pickup with the orchestra in the positions described because he was unable to put his finger on the true difficulty. When one section was too soft, he made the all too common assumption that that section was too far from the microphone. A moment's thought will reveal that when two things are of different volumes, there are *two* possibilities involved: one may be too soft or the other may be too loud. It is necessary to make sure which is which before making changes in a setup. Making such changes is really no different from making an original setup; you must be sure of everything you do. In starting from scratch, an orchestra of this size is bound to have strings, reeds, brass, and percussion. It will be a logical start to place them before the microphone in that order. A couple of numbers should suffice to set roughly the relative distances for sections.

Here enters a theoretical point that is sometimes helpful in practice. Assume for a moment that we have a perfect studio and that we have found that the strings should be 4 feet from the microphone, the reeds 8 feet, and the brass 12 feet. This yields a ratio of two to one and three to one for the other sections as referred to the strings. This means that in our imaginary perfect studio, there would be an infinite number of good setups; that is, the absolute distance is unimportant as long as these ratios are maintained. There would be no detectable difference between spacings of 4, 8, 12; 5, 10, 15; 6, 12. 18; etc. Within restricted reasonable limits this will hold true in our imperfect studios. This fact can sometimes be used to advantage and was in the case of this orchestra. The section distances had been established but the cello and harp were too weak because they were both considerably off side. The sections were redistributed but the distance ratios were maintained. This made sufficient room between strings and reeds to bring harp and cello into center.

Another factor too often overlooked is section "presence." Having section volumes equal is only half the battle; section presences must also be equal. The ratio procedure can be applied here too. Assume that the sections have again been established at 4, 8, and 12 feet for equal volume but that the strings sound "closer" to the microphone than reeds or brass. The "presence" problem can be ironed out by increasing the distances while maintaining the ratios. The general axiom to be drawn from all this is: do not do anything in making or changing a setup unless or until you have a logical reason for doing it. We will call this fundamental No. 3, because No. 2 is closely allied to No. 1 but involves the chorus which will be discussed farther along.

Keep It Simple

All of the original attempts at a setup, both the straight-line and side-by-side types were discarded for a variety of reasons. All of them had one common fault, which, however, was not the cause of their failure. It must be borne in mind that some numbers were played by the full orchestra, some by the dance-band portion of the orchestra, and some by the four-piece jive outfit. In the side-by-side setups two microphones were picking up the orchestra and there was a third one, to and from which the hapless four were supposed to dash madly for their numbers. Aside from any other considerations, the show began to look like a track meet to the studio audience. In the production man's straight-on setup a microphone was in front of each section. There lay the common fault: three microphones. A multi-mike pickup is never quite as clean as a single mike, probably because of the several paths each sound can take. Also, more than one microphone puts the burden of instantaneous balance on the shoulders of the technician. Granted, there are many technicians who can be depended on to do this correctly. Also granted, there are many who cannot. This is not stated in derision of the latter group. It is one of those things that you either have or you haven't. Some people can paint, some can't; some people can repair watches and so on. In any case there is no harm in eliminating microphones. As it turned out, when the large orchestra sections were properly balanced for both volume and presence on the one microphone, the dance band, which was principally the two rear sections, also was well picked up. Further, by having the muted trumpet step down behind the saxophones for the jump numbers, a good pickup was had on the four-piece outfit without so much hundred-yard dash. Fundamental No. 4: strive for simplicity in setups and eliminate as many possibilities of error as possible.

Choral Pickup

The 20-voice chorus contained five members for each of four standard voices: soprano, alto, tenor, and bass. The first consideration was what microphone to use. All different types were tried and the dynamic section of a Western Electric cardioid was finally used. This is a nondirectional unit with excellent high-frequency response. However, any other unit with equivalent highs would have done as well; it just happened that the only tall stand was fitted to take a cardioid. The important thing is that the most common complaint about a chorus is indistinct diction. Diction is distinguishable to the human ear by virtue of the sibilants in the consonant sounds. Sibilants are the high-frequency components of the consonant sounds; hence, a microphone with adequate high-frequency response should be used. Result: impression of good diction. Care must be taken that the microphone also has lows; in other words, a wide range is needed. One which has only highs will give good diction but poor choral effects. Once the particular microphone has been selected, its placement can be considered.

To begin with, it should go on a line through dead center of the group, and back far enough so that individual voices are not prominent. Any inequalities in sections should be adjusted by moving people. Actually as far as choral effect alone is concerned, the microphone can go as far back as studio space will permit. As usual though, circumstances alter cases. If the chorus sings without accompaniment, then there is practically no limit to how far back the microphone can be placed. If there is orchestral accompaniments, as there was in this case, then the microphone will probably have to be placed as close in as it can be without getting individual voices. When the series of programs first started there was always too much orchestra behind the chorus. No type or placement of microphone or separation of chorus effected a solution, simply because none of these things was the cause of the trouble. The arranger insisted on writing full orchestra accompaniments, and any time there are eight brass blowing they are going to be heard above the chorus. The arranger was prevailed upon to use strings and clarinets only, which cleared up the trouble. Fundamental No. 2 which is closely allied to No. 1: know what *can't* be done in your studios with your microphones.

Drama and Novelty Pickups

The drama cast does not offer anything unusual in the matter of setups. If more than two persons are concerned in any one scene, at WHK it is preferred to use a nondirectional microphone so that it may be approached from any direction. This is also convenient for balancing players since it is only necessary to establish a correct distance for each one. Likewise the novelty group treatment will depend on the novelty group. In our case there were five men who played a dozen instruments at different times besides singing at other times. They were also provided with a nondirectional microphone (as a matter of fact it was the same one the drama cast used since they were never on concurrently) so that their only worry was distance. A distance was established for each instrument so that whoever played it had only to move in wherever he could find an opening. To finish up this program, the guest artists, announcer, and master of ceremonies all used the same microphone. Result: Three orchestra groups, a novelty group, a chorus, a drama cast, vocalists, announcer, and master of ceremonies were all picked up on four microphones. With the exception of vocal solos, there was only one microphone open at any one time.

To recapitulate, the following fundamentals can be gleaned from this particular program set up:

1. Be prepared with a full knowledge of what *can* be done in your studios with your microphones.
2. Know what *can't* be done in your studios with your microphones.
3. Don't do anything in making or changing a setup unless or until you have a logical reason for doing it.
4. Strive for simplicity in setups and eliminate as many possibilities of human error as you can.

Small Orchestra

For the sake of definition, consider anything under ten men a small orchestra. Setups for these groups will depend largely on the groups themselves. There is rarely any problem of sectional balance, because it is unlikely that there is more than one section. Usually such a small combination depends greatly on one player. It may be a pianist who is exceptionally good at "noodling," a hot guitar, trumpet, or almost anything else. The type of microphone is moderately unimportant. The best procedure is to place the musician of the type previously mentioned at the best possible advantage with respect to the microphone and then adjust the rest of the group until everyone can be heard. In the case where piano is the mainstay, a separate piano mike is nearly always needed, since it is usually impossible to get the piano close enough to the orchestra mike and still keep it close enough to the rest of the rhythm instruments. One other possible pitfall is the bass fiddle. If it does not seem to be loud enough, it can usually be helped by moving the orchestra mike farther from the group without changing the position of any of the musicians. In small groups, one is likely to run into musicians who double on more than one instrument. Very often both instruments will not pick up equally well from the same position. About all that can be done, short of giving each man an individual mike, is to arrange for him to step forward with the weaker instrument.

Hotel Orchestras

The hotel orchestra is another matter entirely. There is usually no possibility of a logical solution of problems but rather there is a selection of what seems to be the best group of compromises. Except in the more lavish hotels, the band stand, being a place which provides no revenue, is almost sure to be too small and the wrong shape. Because of this the orchestra can hardly be disposed either the way it should be or the way the leader wants it. Since the orchestra geometry will necessarily be side by side, at least two mikes are generally needed for a good pickup. However, the announcer and vocalists can usually use one of these.

It is to be greatly decried that so many stations give these pickups practically no attention. A man comes in and plunks a mike down somewhere in front of the orchestra and that is that. Frequently, a technician is not even sent out, the amplifier being turned on from the studio and the orchestra leader depended upon to place the microphone. All this when a little care will provide a fairly decent pickup. Perhaps this leads us to another fundamental: whatever is worth doing is worth doing well.

Novelty Groups

Somewhat like the small orchestra, the novelty group setup will depend on the group itself. Few if any are strictly instrumental and moving people in for vocals introduces most of the problems encountered. In a group where the members play the same instruments all the time, there is rarely any difficulty either as to choice of microphone or placement. However, when four or five men play ten or twelve instruments and come in for vocal besides, then you are likely to have your hands full.

One such group at WHK was set up with a ribbon mike, because it was thought that the two live sides would afford ample room for four vocalists. This assumption alone was correct, but other considerations made the ribbon unsatisfactory. The man who played bass fiddle most of the time (all of them played it at some time) felt he had to stand in a certain place when he sang. In this position, the bass fiddle was exactly on the dead side of the mike. It was suggested that someone else take the bass fiddle during the singing, but no one else could play it and sing at the same time.

In addition, there was another complication. There were a half dozen other instruments spread around the studio, some of them large (piano, vibraharp, marimba, electric organ, etc.). The effective pickup angle of a ribbon is very little more than 90 degrees for each face. It was difficult to get enough instruments close enough to it and still leave room for the track meet during each number.

The obvious and actual solution was to use a nondirectional microphone which solved the bass fiddle problem and furnished a full 360 degrees in which to deploy all the instruments. It could be argued that more mikes could be used. They could, but the total effect will never be as clean as with a single microphone.

Vocal Groups

The treatment of vocal groups is almost the same regardless of their size. The primary concern is to get a blend so that it sounds like a group rather than a collection of individual voices, which cannot be done with the microphone in too close. In general, the larger the group, the more separation can be tolerated. In smaller groups such as quartets, you may sometimes encounter the rare case where the accompanist plays quite softly. If there is a separate microphone for the accompanying instrument, it may be noticed on loud vocal passages that the voices can be "heard" on the other mike. When this effect is noticed, it will also be noticed that the fader setting on the vocal mike is less than that on the accompaniment mike. Anything which will allow the vocal fader to be higher than the other one will correct the condition. The accompanist can be asked to play louder and thus cause that fader to be reduced. This is not always satisfactory because the accompanist is usually playing softly because that is his or her normal procedure and it will be reverted to after a number or two. The better solution is to move the vocal mike away from the group sufficiently to allow that fader setting always to be higher than the other.

The choice of a microphone should be one with a good high-frequency response. At the same time it should be emphasized that the microphone should have neither highs nor lows; it should be a wide-range instrument. The intelligibility of human diction is centered mostly in the high-frequency consonant sounds. A wide-range microphone is indicated to reproduce adequately the vocalists' words.

Piano Pickup

The subject of piano pickups, if not the most controversial, is at least the most varied problem in the business. Microphones have been placed under the piano, in it, beside it, across the studio from it, over it, in fact everywhere but in the performer's pocket. The lid has been opened, closed, and off. Correct piano pickup follows a series of logical principles, so that if any trick procedures have been successful, they have also been illusions. In other words, somebody's ears are defective, some studio equipment is defective, or an accident has occurred which compensated for a studio deficiency.

Let us start off with a little theory. We need concern ourselves only with grand pianos, because few if any studios use any other kind. The grand piano was designed with two things in mind. If all conditions are perfect the maximum efficiency should be expected (1) with the lid on full stick and (2) at some position on an imaginary extension of the hammer line. That is all there is to the theory.

Next, the problems likely to be encountered. All pianos are not built with equal care, so you may find that your particular one has a more brilliant bass than treble or vice versa. Pianos which were originally good may have become tonally lopsided through age, lack of care, or misuse. Regardless of the condition of the piano, each pianist is also a separate problem. Some play softly, some loud, some have a heavy right hand and some a heavy left. Finally, we have to deal with the characteristics of the studio in which the piano is located.

There are two adjustments of microphone position which will handle any or all of these variables. Going back to the theory for a moment and assuming a perfect piano, perfect pianist, and perfect studio conditions, the microphone should be on the imaginary extension of the hammer line about 8 to 10 feet from the piano. The first adjustment, if necessary, will be on account of studio acoustics. If the studio is very live, the 10-foot distance may give more reverberation than is pleasant. The microphone should be moved straight in on this imaginary line until the noticeable reverberation is reduced to a pleasing amount. The second adjustment is for bass-treble balance. This one will work regardless of the reason for the unbalance, whether piano or pianist is at fault. If the treble needs to be increased, the microphone will have to be moved in still farther on the afore-mentioned imaginary line. In extreme cases it has been necessary to move the microphone all the way up to the piano case, lower it, and tilt it toward the treble strings. Now, mentally restoring yourself to the microphone position where reverberation was just right, assume the bass is weak. While maintaining the proper reverberation distance from the piano, move the microphone toward the tail of the piano. This will increase the pickup from the bass strings and decrease the pickup from the treble strings.

With the above procedure in mind, it should never be necessary to use a grand piano any other way than with the lid on full stick. That is the way the piano was designed to be used and that is the only way the piano sounds normal. Taking the lid off, putting it on the half stick, or closing it only seems to do something which could be done better some other way. For instance, putting the lid on the half stick does not reduce volume appreciably but it will muffle the tone considerably.

A two-piano pickup involves the same principles as with one piano. It is usually more convenient to make adjustments in this case by holding the microphone position constant and moving the pianos. There is one added problem: temperament of the pianists. Assuming perfect conditions again, the hammer lines of both pianos should be on the same imaginary contiguous line. The pianos should be about 15 feet apart with open lids toward each other. The microphone should go half way between them on the imaginary line. The two principles mentioned for one piano apply equally well to two pianos. In addition, if one pianist plays more heavily than the other, the microphone can be moved closer to the weak one.

Now another problem: the temperament of the pianists. Many two-piano teams like to be closer together than 15 feet. If they cannot be talked out of it, some of the clarity and brilliance of the pickup will have to be sacrificed by moving them closer together. If you refuse to do so, the pianists will play either badly or not at all, so you will not have anything anyway. Sometimes the players will insist upon having the pianos right together and side by side. This very nearly prevents a first-class pickup. There is some hope, however, if the same pianist always plays the lead part. In this case the lead piano should be closer to the microphone, which is placed as if for one piano only high enough to clear the top of the lead piano lid. Balance between the two pianos can usually be accomplished by raising or lowering the microphone. Raising it helps the second piano.

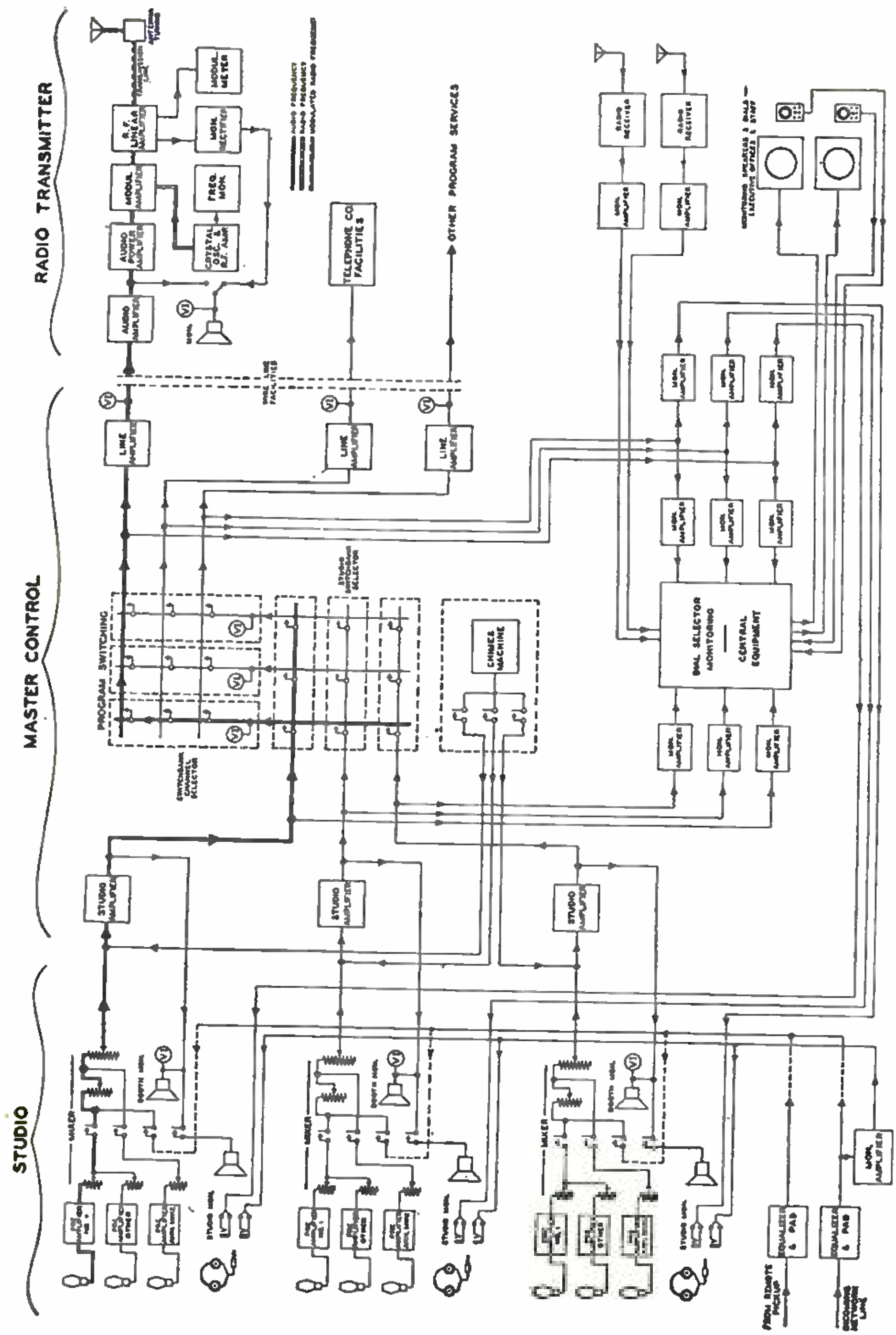
In picking up piano with a small orchestra, clarity and brilliance are mostly buried in the sound of the orchestra so the preceding practices can be more or less ignored. It will be found that the microphone has to go very close to the piano. Also, if possible, the piano should be oriented so that the open lid physically masks from the microphone most of the orchestra, or at least the loudest instruments.

Piano with symphony orchestra is entirely another matter. Referring to the setup described for the symphony orchestra broadcasts at Severance Hall in Cleveland, the place normally occupied by the conductor is occupied with the piano. An additional microphone is used for the piano a sufficient distance away so that the presences of the orchestra and piano are the same. The piano microphone is opened only enough to provide a little definition. Many piano-with-symphony programs are ruined on the air by making the piano too loud. Much of the time in this type of composition the piano has a supporting rather than solo part.

Organ Pickup

There is little that can be said about pickup of pipe organ. The type and make of organ and studio size all vary so widely that there probably are not two identical setups in the whole country. It simply remains for each technician faced with such a problem to use horse sense and ingenuity to secure a satisfactory pickup.

Electric organs present somewhat less difficulty. The older type speaker with openings on both top and side were pretty much a headache. There was not much that could be done to get a really good pickup. The newer type speakers with opening on the side only are duck soup. Just place a microphone straight out in front at whatever distance gives the desired amount of reverberation.



Courtesy NBC

Fig. 6-1. Simplified schematic of the NBC layout, showing how individual studios are connected through the master control to the transmitter.

Part 2

OPERATING THE MASTER CONTROL

Chapter 6

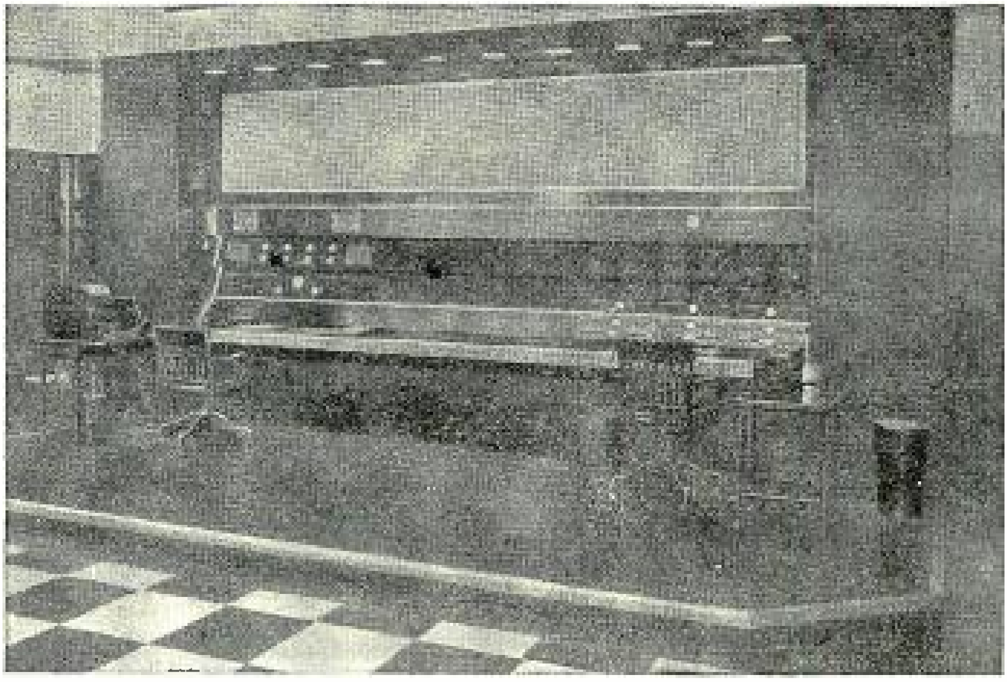
WHERE SPLIT SECONDS COUNT

In station setups where a comparatively large number of individual studios are involved, a central switching point known as "master control" is employed. Fig. 6-1 shows a simplified schematic of the NBC technical layout. This illustration shows how individual studios are connected through the switchbank selectors to the master control position, where the program or programs may be routed in any way desired. Fig. 6-2 is an illustration of NBC's Chicago master control.

The NBC program switching system is a standardized layout for all key stations of the network. Since more than one program is being handled at any one time, the setup must be as flexible and foolproof as technically possible. This calls for operation on a preset basis, eliminating as far as practicable confusion of switching a number of program sources in the split seconds allowed.

In the NBC system, the switchbank selector is a group of relays associated with outgoing channels, arranged for a single connecting means between any group desired and any single program input. A brief description of operation of the program switching system is as follows.

The program sheets or schedule sheets prepared in advance by the program and traffic departments indicate the program sources such as studio (and the particular studio number), for a remote point, or incoming network line. Also indicated are the outgoing channels feeding various points with the programs. At the start of operations, the channels required for each separate program are preset by operating numbered key switches in master control which are connected to separate switchbanks. Any switchbank is then connected to any program source at the proper time by operating the associated key switch on the switchbank selector panel, one panel being associated with each studio or other program source. This operation actuates the "carrier" lights at both the announcer's control desk in the studio and on the engineer's console in the control room, and is the signal for the pro-



NBC Photo

Fig. 6-2. The master control at the NBC studio in Chicago.

gram to begin. In this way, programs are routed to the station's own transmitter and to the various other sources such as network, f.m., or special circuits such as international short wave.

Master Control of United Broadcasting Company

WHK master control is definitely not standard; it has grown through the years from the personal preferences of master control operators. From the foregoing statement it might seem to some that it would be a most glorious hodge-podge of gadgets by now. Actually it is the most simple and flexible system that could be imagined.

All program sources, each studio, the network, and four remote positions go to individual 12-tube repeater amplifiers. This provides twelve copies of each program source to be used for local station, network feed, f.m., monitor systems, etc. On the master control console are six banks of mechanically interlocking switches which route any program source to any or all of six line amplifiers. The interlocking is to prevent more than one key being depressed at any one time. The switchbank for WHK's line amplifier is different from the rest. Here, any program source can be put on any one of three faders, and interlocking prevents getting more than one program on any one fader. The faders in turn feed the line amplifier. The faders are considered necessary to smooth operation for getting in or out of programs late or early. There are no relays in any program circuit. One line amplifier feeds WHK's transmitter, one for the Mutual Network, one for an Ohio network, and three spares which can be used for anything. Also on the console itself are two switching panels which route any of 30 remote lines to any of the four remote positions. These same panels have facilities for line reversal and private telephone to each remote.

In addition to the console there are three banks of double depth relay racks which house (1) power supplies, (2) all program amplifiers, and (3) monitor amplifiers. Every piece of audio equipment is brought out to normal through jacks so each one may be replaced or removed from circuit in a few seconds in case of failure. All amplifiers have pads connected to their input jacks to take plus 8 vu down to whatever is necessary for that amplifier. This makes it possible to have every input and output plus 8 vu at 600 ohms. Even a shoemaker couldn't hurt anything by patching them all in series.

Function of Master Control Operations

Every individual station employing a master control has, of course, slightly different "rules and regulations" of procedure to suit their individual requirements and to satisfy the technical executives who are responsible for the co-ordination of all operations. The following rules of studio procedure that were compiled by the engineering supervisors of WBBM for guidance of their technical staff is presented here to acquaint the reader with general master control operations. The rules are divided into three sections: (1) master control, (2) studios, (3) field. The letters *M*, *S*, and *F* have been used respectively to differentiate between these sections in numbering. Since all are closely tied in with the duties of the master control operator, they are presented here in their entirety.

MASTER CONTROL PROCEDURE

M1 Checking of New York Daily Operations Sheet

The Master Control engineer is required to check the routings of all network originations with the New York Daily Operations Sheet, and to compare the routings listed with those on the WBBM Daily Operations Sheet.

M2 Booth Check-in

For procedure to be used on a booth check-in, see *S5*. In addition, the Master Control engineer is to record on the WBBM Daily Operations Sheet, above the engineer's name, the time of the check-in. Should the studio engineer report someone as absent, Master Control should immediately notify the Program Department.

M3 Time of Making Preset

All relay presetups should be made approximately four (4) minutes before each regular switching period (see Glossary).

M4 Use of Switching Light

The signal for Master Control to switch from one studio (excepting studio M7) to another, *on all local originations*, will be the switching light.

M5 Checking Equipment

All equipment is to be carefully checked for gain settings, tube currents, etc., before being placed in service.

M6 Filling During Network Failures

For procedure see *S18*. In addition, on all scheduled stand-bys and all emergency fills to the network, Master Control is to patch the stand-by studio's cue speaker to the incoming network line.

M7 Cutting of Local Programs Running into Network Commercials or into Synchronization

All local programs running into synchronization or into network "musts" which are to be carried by WBBM, will be cut by Master Control only.

M8 Relieving of Engineers

a. A relief engineer is not to take over the Master Control if only (5) minutes or less remain before a switch. The engineer being relieved is to make the switch and see that the program or programs start properly.

b. An engineer is not to be relieved of duty until he has cleared the patching bays of all unnecessary cords.

M9 Checking Program Level

Master Control engineers are to keep a close check on the level of all programs, and to see that the proper level is maintained at all times. See also *S9*.

M10 Remote Check-in to Master Control

The Master Control should see that all remote engineers check in by twenty-eight (28) minutes before air time. If the remote has not been heard from by twenty (20) minutes before air time, provision should be made for a stand-by.

M11 Testing of Field Equipment

Remote engineers, before leaving the building for "pickups," are to give Master Control an audio test of their equipment. This equipment is not to be O.K.'d other than in good condition. The time of these tests is to be recorded on the WBBM Daily Operations Sheet, opposite the particular pickup, with the Master Control engineer's initials.

M12 Patching Up Remote Talk-Lines

Remote talk-lines are to be patched up only after the scheduled Studio engineer arrives in the booth and requests them.

M13 Recording of Inability of Studio Engineers to Get Program Procedure

All reports by Studio engineers of inability to ascertain the procedure on a particular program are to be recorded in the "penciled" comments, with the reasons and name or names of persons concerned.

M14 Making Setup for Following Morning

The engineer signing off each evening is to make the necessary setup in Master Control for the following morning, in order that the Studio engineer can put the station on the air should the Master Control engineer fail to arrive.

M15 Changes to the WBBM Daily Operations Sheet

All changes and notations to the WBBM Daily Operations Sheet are to be made in ink and initialed by the Master Control engineer.

M16 Signing of Engineering Department Copy of WBBM Daily Operations Sheet

Engineers must sign on the Engineering Department copy of the WBBM Daily Operations Sheet the time "ON" and the time "OFF" duty.

STUDIO PROCEDURE

S1 Ascertaining of Program Procedure

The engineer is required to acquaint himself with the procedure of all programs on which he is assigned. This is required regardless of the number of times the engineer may have been assigned to the show. If at any time it is impossible to secure this information, Master Control is to be notified in order that it may be entered in the "penciled" comments.

S2 Time of Check-in to Master Control

Studio engineers are to check in to Master Control not later than seven (7) minutes before air time.

S3 Remaining in Booth

Engineers are to remain in the booth between the time of checking in to Master Control and two (2) minutes after the program. It is, however, permissible to leave for the purpose of making a necessary last-minute change in the studio setup.

S4 Checking In for Rehearsals

Engineers scheduled on rehearsals are to report to the studio ten (10) minutes early, and have all equipment tests completed by rehearsal time. The failure of producer or talent to arrive does not relieve the engineer of this responsibility.

S5 The Check-in to Master Control

The check-in to Master Control is to be made as follows:

"*John Doe* checking in from studio three, T-H-R-E-E, for Columbia's School of the Air, *2:30—2:59½*, to SRR-NW-TC (give complete routing).

"The time is *2:20 and 40 seconds*. Woof!"

If it is a local program only, the engineer is to add after the routing that there *is*, or *is not*, a spot announcement following his program, and, if so, the studio in which it is scheduled.

It is the responsibility of both the Master Control and Studio engineer to make these check-ins carefully. The Master Control will repeat and spell out the studio number.

When making check-ins it will be understood that, *unless Master Control is informed otherwise*, all tests have been completed and *all* talent, including the announcer, is present.

S6 Time of Arrival in Booth on Remote Programs

Engineers are to arrive in the studio at least thirty (30) minutes before air time, if schedule permits, on all remote commercials and special events; on all other remote programs the minimum time is fifteen (15) minutes.

S7 Patching Up Remote Talk-Lines

Remote talk-lines are to be patched up only after the scheduled Studio engineer arrives in the booth and requests them.

S8 Studio Line-up with Remotes

The studio line-up with remotes should include the following, and preferably in the order shown:

1. Line and equipment test.
2. Level check (the Field engineer will call peaks).
3. Name and sequence of musical selections (if it is an orchestra).
4. Corroboration of air time.
5. Time check.

S9 A Proper Level to Be Maintained

It is the duty of the Studio engineer assigned to a program to maintain a proper level at all times. If the level from a remote is abnormal, correct it and then ask the Remote engineer to either raise or lower it.

S10 The One-Minute Warning

One minute before air time Studio engineers are required, first, to "kill" all microphones and give a one-minute warning over the "talk-back" mike to studio talent; and second, if a remote is scheduled, to give a one-minute warning over the telephone to the Remote engineer (see *F5*, a). After these warnings, the "talk-back" mike is to be disconnected.

S11 Remaining in Booth After Air Program

Engineers are to remain in the booth, and equipment must be left turned *on* for at least two (2) minutes after each air program.

S12 Use of Switching Light

The signal for Master Control to switch from one studio to another on all originations for WBBM *only* is the switching light. Hold the switch on until the channel light is removed.

S13 Turning On Cue Speaker

The WBBM cue speaker is to be turned on immediately after the one-minute warning preceding the start of the program for the purpose of ascertaining the time the channel will be received.

S14 Reporting of Trouble on Tests

All trouble encountered on tests preceding an air program must be reported to Master Control *immediately*.

S15 Filling Out of Program Report

An Engineering Program Report is to be filled out in full by the Studio engineer after *each* air program where there has been an interruption to the *normal* routine. This report is to be deposited in Master Control reasonably soon after the program.

S16 Disposition of Mikes and Cords After Each Program

After the completion of each program or a succession of programs from the same studio, all mike cords are to be rolled up and placed in a corner, and microphones are to be returned to their designated places in the Maintenance Department.

S17 Network Breaks: Length and Level of Sustaining Background

a. All regular closing network breaks and breaks used for split-network switching are of thirty (30) seconds duration, with the sustaining background faded out after fifteen (15) seconds.

b. All network breaks during a program which are used for station identification *only* are of twenty (20) seconds duration, with the sustaining background supplied for the entire period.

c. The level of the sustaining background during all CBS breaks is to be lowered to 30 (—10 vu).

S18 "Filling" During Network Failures

When standing by for the network or any portion thereof, should a failure occur or trouble develop which renders the program unintelligible, the "fill" should be made as follows:

First: In order to know *when* the trouble has cleared, turn on the CBS cue speaker, which Master Control has patched across the incoming line.

Second: Wait forty-five (45) seconds, and if by then the trouble has not cleared, fade off the incoming line and signal the stand-by announcer to make a courtesy; the "stand-by" should then be supplied.

Third: Immediately after the trouble has cleared on the cue speaker, the announcer should be signaled to make a second courtesy announcement rejoining the program.

Fourth: Fade out the "stand-by" and fade up the program.

In connection with the second and third items above, it should be understood that should a situation arise whereby an announcer is not available, the procedure remains the same with the exception that the courtesies are deleted.

S19 Procedure in Remote Program Line Failure

The following procedure is to be followed should a remote program line develop trouble:

If the trouble develops before air time, Master Control is to be notified, and both points (Master Control and Field) will then reverse lines. The remote engineer should then feed a test as usual. One minute before air time Master Control will disconnect the remote feed to the studio (to guard against a feedback), and supply "cue" over the substitute program line. The remote should then start the program *five* (5) *seconds after the proper cue,* which will be heard on the monitoring phones. This five seconds will be used by Master Control in normaling the feed to the studio. If the remote program consists of an orchestra which is to be announced from the studio, five (5) seconds will be allotted between musical selections.

The foregoing procedure is formulated, of course, on the assumption that the regular program line cannot be used even for cue purposes.

S20 Channel Lights: Taking Away of

Unless Master Control directs otherwise, the channel light or lights on *each* network origination will be taken away fifteen (15) seconds after *a*, the middle CBS cue (if any), which is used for split-network switching only, and *b*, the closing CBS cue. In the case of *a*, the channel light or lights will be returned in the regular manner (see *S21*).

S21 Signal Used to Begin Network and Local Originations

a. All regular network originations will start five (5) seconds after the channel light or lights are received.

b. All regular local originations will start *immediately* upon receipt of channel light or lights.

S22 Network and WBBM Remote Originations: Opening "Go-Ahead"

All originations for both the network and WBBM which open from local remotes will start by a verbal "go-ahead" from the Studio engineer.

S23 The Cutting of Local Runovers

On local "runovers," all cuts which are made necessary because of synchronization or network "musts" to be carried by WBBM, will be made by Master Control.

S24 Nonrelief Period of Engineers

When programs originate consecutively in the same studio, engineers are not to relieve each other during the last three minutes of a program and the first two (2) minutes of the following program, and then only after the relief engineer has familiarized himself with the routine of the program or programs.

S25 Turning Off of Equipment

With the exception of studio three (3) after 6:00 p.m., all equipment *is to be turned off* when it is not being operated by *a member of the Engineering Staff.*

S26 Studio Engineer Should Be Able to Put Station on the Air

Should the Master Control engineer fail to arrive for a "sign-on," the Studio engineer should be able to put the station on the air. For this reason, he should acquaint himself with the operation and setup of the following equipment:

1. Battery supply, and associated switches.
2. Local relay channel.
3. Patching of phonograph to studio.

See also *M14*.

S27 Use of Telautograph

Corrections to the WBBM Daily Operations Sheet will be written on the Telautograph. The engineer upon arriving in a booth should note all corrections affecting him, and change his own schedule accordingly.

S28 The Daily Work Sheet and Weekly Time Sheet

a. A Daily Work Sheet is to be filled out in full each day and deposited in the box provided in the Maintenance Department.

b. The Weekly Time Sheet, which is posted on the bulletin board in the Maintenance Department, is to be filled out each day showing the number of hours worked. This sheet is to be initialed by the engineer at the end of the week.

FIELD PROCEDURE

F1 Returning of Field Equipment

Field engineers are required to return equipment to the Maintenance Department after the engineer's last pickup for the day, and place it in its proper location.

F2 Doors That May Be Used When Taking Equipment In or Out of Building

Field equipment may be carried in or out of the Wrigley Building through any door *except the front door* up to 6:00 p.m. After this time, call for a building watchman to open a side door.

F3 Guests on Pickups

Engineers are not to take guests to remote pickups at any time.

F4 Testing Remote Equipment

Engineers before leaving for the field must give their equipment an audio and mechanical test as follows:

First: Check 1) microphones and cords for defects; 2) quality; 3) output level; 4) microphonics; 5) tube shields, observing that they are in properly, etc.; and 6) volume indicator.

Second: Recheck the first four foregoing items with Master Control.

F5 Check-in and Line-up from Field

a. Remote engineers are to check in to Master Control with an equipment test at least one-half hour before air time on *all* programs (see also *M10*). Leave a test on the line until the one-minute warning, which will be given over the telephone by the Studio engineer, and then fade out the equipment.

b. The line-up to the Studio engineer should include the following, and preferably in the order shown:

1. Line and equipment test.
2. Level check by calling peaks.
3. Name and sequence of musical selections (if it is an orchestra).
4. Corroboration of air time.
5. Time check.

On "3" above it is the duty of the Remote engineer to check carefully the name and sequence of musical selections with the orchestra leader.

F6 Lowering of Sustaining Music

On all remote orchestras which are announced from the studio, the Remote engineer is to lower the level of the sustaining between musical selections to 30 (—10 vu).

F7 Procedure in Remote Program Line Failure

See *S19.*

F8 The Daily Work Sheet and Weekly Time Sheet

See *S28.*

GLOSSARY

Channel Lights. The small circle of lights found in the center of each booth console and used as *the* signal which that studio is feeding an "outgoing" line. Each light represents a separate line.

Check-in. The verbal report by the Studio engineer to the Master Control that he or she (i.e., the Studio engineer) is in the booth for his or her next program (see *S5* and *M2*).

Cue Speaker. The small speaker located in the booth console which can be patched by Master Control to either the local or the network program.

Daily Log. See *Master Control Log.*

Daily Operations Sheet. See *New York Daily Operations Sheet.*

Daily Schedule Sheet. The schedule which shows the rehearsal time, air time, studio number, destination (i.e., network or local), and the name of the engineer assigned to each program. This schedule is posted on the bulletin board in the Maintenance Department each evening for the following day's operations.

Daily Work Sheet. A form which is to be filled out by each Studio and Remote engineer every day showing the name and time of all rehearsals and air programs worked.

Engineering Program Report. A report filled out by Studio engineers for the information of Master Control, and which explains any and all interruptions to the normal routine of an air program.

Master Control Log. The daily record of all abnormal operations kept by Master Control.

Network. The entire Columbia Broadcasting System or any portion thereof.

Network Break; CBS Break. The 30- or 20-second period at the end or in the middle of each program which is used for station identification. It always follows the words, "this is the Columbia Broadcasting System."

New York Daily Operations Sheet. The New York Daily Schedule which shows the exact network routing of each program.

One-Minute Warning. The warning that everyone should remain quiet, given to talent in the studio and/or a remote one minute before a program is scheduled to take the air.

"Penciled" Comments. The log kept by Master Control in which is recorded only material of a purely engineering nature.

Regular Program Schedule. See *WBBM Daily Operations Sheet.*

Remote. Any program originating at a point outside of the studio from which that program is controlled.

Split Network. A broadcast period during which time the Columbia Network is divided into two or more sections; i.e., more than one program is being originated at the same time.

Switching Light. A light located in Master Control and turned on by a switch on each booth console. It is used to signal the Master Control engineer to switch to the following studio or program.

Switching Period. Each quarter hour, i.e., the 15-, 30-, 45-, and 60-minute period.

Synchronization. The period after sundown each day during which time radio stations KFAB and WBBM broadcast simultaneously on the same frequency.

Talent. The person or persons associated with a program and who will be heard on the air during that program. This includes the announcer.

Talk-Back. The equipment used in speaking from the booth to the talent in the studio during rehearsals.

Trouble-Report Form. The report filled out by each engineer and filed with the Maintenance Department for each piece of equipment found defective.

WBBM Break; Local Break. The station identification.

WBBM Daily Operations Sheet. The official schedule of program operations for the day for WBBM.

Part 3

OPERATING OUTSIDE THE STUDIO

Chapter 7

REMOTE-CONTROL PROBLEMS

THE HISTORY of the development of radiobroadcasting since its earliest days, when the mere broadcasting of actual sound was miracle enough to create unbounded interest, has witnessed an almost fantastic evolution of technical equipment and technique of operation. Even during the earlier period when amplifier response and the old magnetic loudspeakers so limited the possible fidelity capabilities, broadcast engineers recognized the troublesome problems associated with the room or "studio" in which the program originated. Ordinary architectural construction did not satisfy the requirements for smooth control and faithful reproduction. This led to a detailed study and development of both architectural design and acoustical treatment to suit the needs of broadcasting. Although many experts believe that the final answer to this problem has not yet been found, they all concede that modern broadcast studios have spelled the difference between the success and the utter uselessness of high-fidelity amplifiers, microphones, and line or relay links.

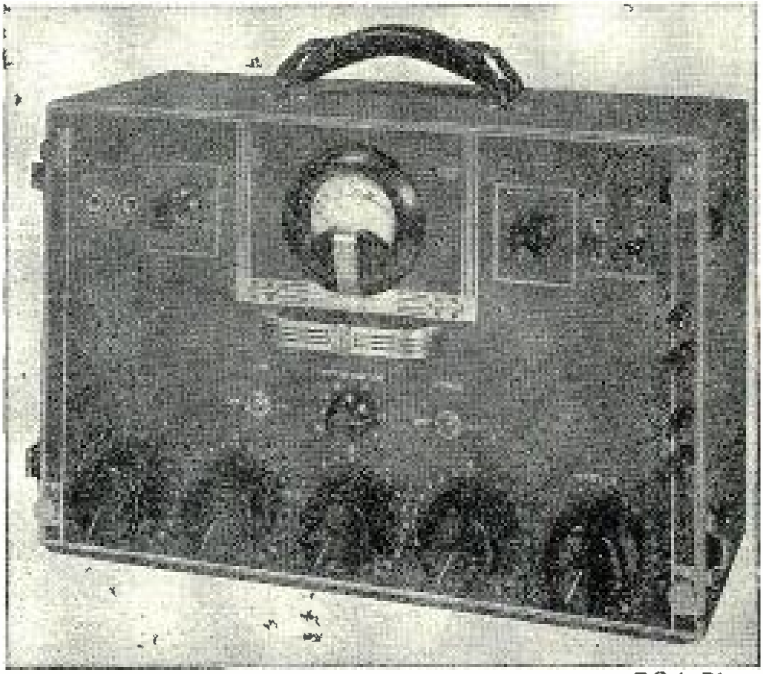
Broadcast programs, however, are as varied as the interests of the more than twelve-million people who comprise the listening audience. It is inevitable that a great number of programs must originate at some point other than in a carefully designed studio with a permanent and complex studio control console and amplifier racks. Such programs as speeches and political rallies, news commentators "on the spot," audience participation shows from theatres or auditoriums, sports, religious programs from churches, popular music from night clubs, classical music from concert halls, and novelty and variety shows from theatre stages necessitate a special department at each broadcast station to handle such events adequately.

There are certain exacting requirements for remote-control equipment. The remote operator will encounter conditions that will be far from favorable for the type of program to be broadcast. If the specific location produces very decided effects, he must either use them to his advantage or avoid them. It is the purpose of Part 3 of this handbook to outline the general type of remote-control equipment, and to discuss comprehensively the problems encountered in the best utilization of this equipment to achieve the desired results.

REMOTE-CONTROL AMPLIFIERS

Equipment used for remote-control broadcasts must provide the same means of mixing the outputs of the microphones and sufficient amplifier gain for use of low-output high-quality microphones as does the main studio equipment. It is obvious, however, that the equipment must be conveniently portable and therefore limited in size and weight. For this reason, nearly all amplifiers of this type use low-level mixing circuits requiring only one preamplifier tube for all microphone inputs. Since mixing potentiometers are in the extremely low-level position, frequent cleaning is mandatory. Power for remote equipment is supplied either by batteries or power line current where available, or by dynamotor supply in some cases of mobile equipment.

Fig. 7-1 is a panel view of one type of remote amplifier with self-contained batteries and provision for four microphone inputs. The



RCA Photo

Fig. 7-1. One type of battery-operated remote-control amplifier with provision for four microphones.

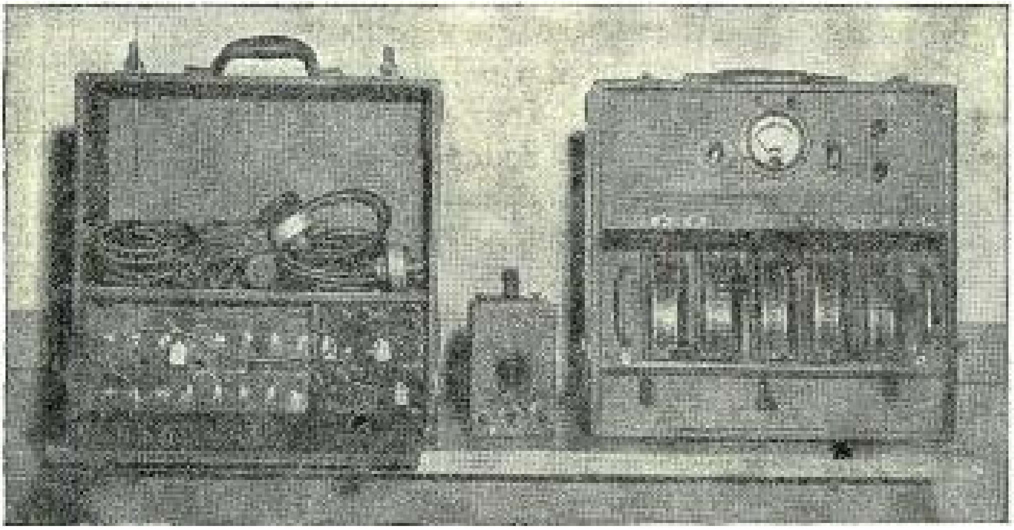
RCA OP-5 weighs only 36 pounds when completely loaded with batteries and is a convenient size to carry. The line key switches shown at the upper right in Fig. 7-1 enable either of two lines to be connected to the output of the amplifier, or to a socket on the rear of the chassis where an interphone may be plugged in for a talk and cue line. Specially developed nonmicrophonic tubes are used, which have high gain and low battery drain. Tubes may quickly be reached through the door on the front panel which mounts the *V.I.* meter, and the entire chassis may be removed from the case by simply loosening the four corner thumb screws shown in the illustration.

Since the level requirements for remote-control lines will vary with conditions, provisions are made for a multiplier arrangement on the *V.I.* meter so that zero reference may actually range from minus 6 to plus 6 db. On some long open wire lines, for example, it may be advisable to feed a higher level to override line noise.

One example where this was found necessary occurred on a field broadcast handled from the Indianapolis Municipal Airport which consisted of interviews of incoming passengers from the planes. The remote amplifier was battery operated, but the signal from the control tower transmitter was feeding through so strongly on the broadcast line that the tower operator completely swamped the announcer when feeding a "zero level" to the line. By adjusting the V.I. multiplier switch to +6, and peaking zero on the V.I., the tower operator was down far enough below the program level that, when he came on with instructions to the pilots, he simply provided an "on-the-spot" atmosphere to the program without spoiling it entirely.

Equipment used for remote-control purposes is largely an outgrowth of the personal preference of the particular station, and therefore varies considerably from one station to another. Remote-control facilities are more apt to be built up by a station to meet individual requirements than any other type of the station's equipment, such as control consoles and transmitters. Fig. 7-2 illustrates the series of amplifiers built up by the staff of WHK (United Broadcasting Company), tailored to meet their preference in remote equipment. Remotes may require anything from one microphone to a dozen. It is undesirable to carry a big amplifier to a one-microphone remote, and it is confusing from a maintenance standpoint to have a great many different kinds of amplifiers. With this thought in mind, WHK engineers designed this series of amplifiers which are all essentially the same. There are three types of amplifiers in the series, all of which have the same physical dimensions and the same internal circuits. All types have the following common characteristics:

(1) 15 x 7 x 6 inches made from two standard 15 x 7 x 3-inch chassis pans.
(2) Preamplifier for each input which the staff felt necessary to improve the signal-to-noise ratio.
(3) Facilities to feed two separate 600-ohm outputs with +8 vu level.
(4) High impedance output with separate gain control for feeding a p-a amplifier.
(5) High level earphone jacks with separate gain control.



Courtesy of Station WHK

Fig. 7-2. Amplifiers for remote-control work must be portable and compact. Details of these illustrated are listed above.

The basic unit has four inputs, uses 6-volt tubes, and has an a-c power supply and emergency batteries in another case the same size as the amplifier. This type is used on dance band and night spot remotes. The subbasic unit has two inputs, uses 1.5-volt tubes, and the batteries are in the same case. This type is used for the one- and two-microphone pickups. The superbasic unit has eight microphone inputs plus a high level input, uses 6-volt tubes, and the same power supply as the basic unit. The high-level input allows two or more amplifiers to be connected in series so that any number of microphones can be handled.

Simplex Control of Remote Amplifiers

Many times it is highly desirable from an efficiency point of view to allow turning the remote amplifier on and off from the studio. This is desirable for a regularly scheduled broadcast from a point requiring only one microphone where no "mixing" adjustments are necessary.

This may be accomplished by means of a "simplex" installation as shown in Fig. 7-3. The simplex coil "in" and "out" appears on the jack panel at the studio. When the remote line is patched into the

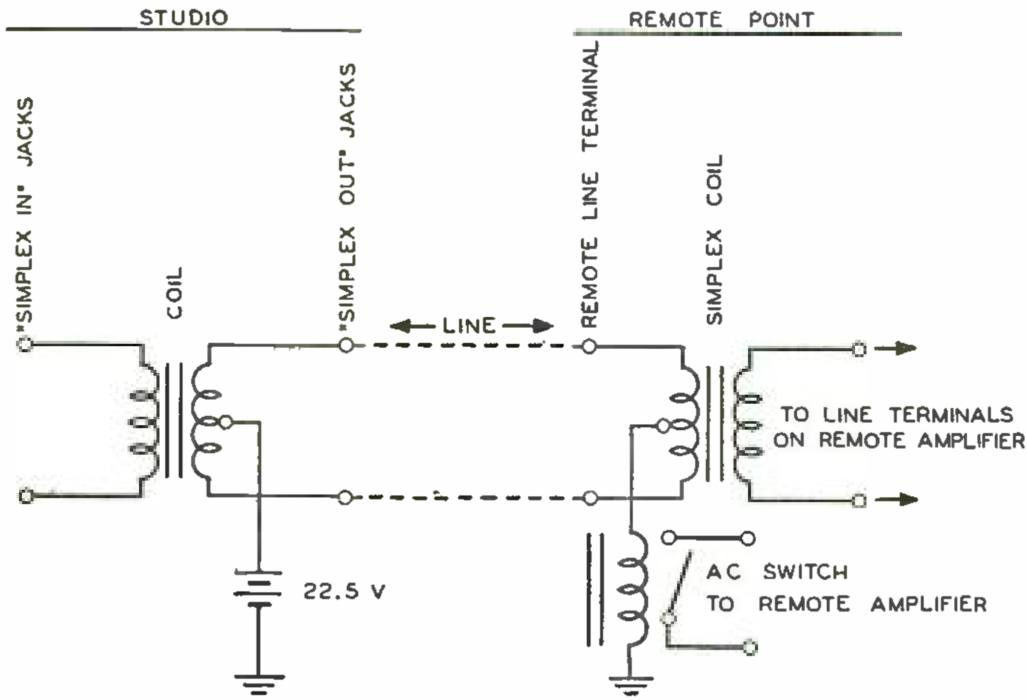


Fig. 7-3. A simplified schematic of a "simplex" installation which is used to switch on and off a remote amplifier from the studio.

equipment through this coil, it may be seen that the battery circuit will be completed to activate the relay at the remote point which is in the power-supply circuit of the remote amplifier. This procedure eliminates the necessity of sending an operator to this point each day.

General Remote Operating Problems

The remote operator is faced with conditions so varied and complex that any discussion of a specific type of pickup must necessarily present only general principles involved.

A singer's voice is given a certain recognized timbre by the breath which carries the sound from vibrating vocal chords into the modifying air cavities of the head. As these sound waves emerge they disturb the air in the place of origin in all directions, but principally in the direction which the singer is facing. The microphone will pick up the sound anywhere in the room. Good transmission will depend upon the relationship of the position between performer and microphone, and also upon the relationship of position with the walls, floor, and ceiling of the room. The air cavities and acoustical condition of the air boundaries will affect the character or "timbre" of the sound just as do the air cavities of the singer's head which determines his original voice quality.

Thus it becomes apparent that the varied acoustical conditions encountered will place considerable importance on the type of microphone to be used and method of placement of the microphone. For example, the operator may find the surfaces bounding the point of pickup to be highly reflecting in character to sound waves, causing distinct "slaps" and echoes to be prevalent. This condition is caused by deflecting surfaces parallel to each other, and is the reason why "live-end" broadcast studios are constructed with no parallel surfaces existing. Under this kind of handicap, the operator must use the directional characteristics of the microphone to the best advantage. He could not, for example, use a bidirectional microphone with one live side toward the pickup and the other live side toward a highly reflecting wall.

Due to the nature of remote-control pickups, the microphones used are nearly always of the unidirectional type. This permits much better discrimination between wanted and unwanted sound, since the noise level at any remote point is quite high compared with a broadcast studio. The unidirectional characteristic is convenient to aid in preventing large amounts of reflected sound-wave energy from actuating the microphone elements. Since the intensity of a sound wave decreases as the square of the distance, increasing the distance between the sound source and the reflecting surfaces (where this is possible) will decrease the amount of reflected sound-wave energy at the microphone.

By experimenting with the distance between sound source and microphone it may be observed that the relationship between original and reflected sound will vary over a considerable range. Thus by decreasing this distance a greater proportion of original sound is obtained, and by increasing the distance (between wanted sound source and microphone) a greater proportion of reflected sound is obtained. Music in particular needs a certain amount of reflected sound for brilliance and color. Too much reflected sound will cause a "hollow" tone and uncomfortable overlapping of succeeding musical passages. If the amount of reflected sound is too small, such as in many studios overtreated with sound absorbent material, the music will be lifeless.

Chapter 8

REMOTE VERSUS STUDIO PICKUPS

THE PROBLEM of broadcasting concerns the transmission and reception of voice and music with the preservation of all the original values. This precludes that any effect should be added to or withdrawn from the original intent. In radio, sound can play on the emotions of the listener only as effectively as the transmitter and receiver equipment, studio conditions, and the skill of the engineers will permit. Microphones and amplifiers are today of such good quality that no practical limitations to true fidelity exist from mechanical or electrical characteristics. Modern broadcast studios are such that only slight limitations exist for faithful transmission of sound. This emphasizes, insofar as remote-control broadcasting is concerned, that the skill of the engineer or producer responsible for microphone setups and operating technique, is of utmost importance. This becomes doubly important when it is realized that each orchestra of any type has its own identifying qualities resulting from instrumentation, musical technique, and conductor's interpretations, all under the influencing factor of microphone placement and acoustical conditions of the point of origin.

The effects desired by the orchestra conductor may be achieved only by proper relationship of the microphones to the musical instruments. This "proper relationship" is directly influenced by the acoustical condition of the pickup area. For transmission of pure musical tones of a violin, the microphone must be far enough away from the sound holes of the violin that the reflected sounds may be caught in all their beauty denoting rich and true harmonic content. Conversely, when special effects are desired such as in many instrumentations of rumbas in dance orchestras, the microphone should be so near the violin as to bring out the harshness of the resined bow drawn across the strings of the instrument.

General Comparisons of Studio and Remote Pickups

Perhaps the most striking difference between studio and field pickups is the complete lack of permanent facilities of any kind in the field. The Bell Telephone System installs a "broadcast loop" upon order from the program or traffic department of the station. Sometimes two loops are installed, one to be used as a "talk" line direct to the control room at the studio, or for emergency broadcast service in case of trouble with the regular broadcast line. These lines, however, must be installed as conveniently as possible to the source of the broadcast, yet as inconspicuously as can be arranged. For this reason, it is often a matter of a "line hunt" on behalf of the field engineer, and this is one reason why he arrives at the remote point a long time in advance of broadcast time. The line or lines may be found under tables, behind chairs, piano, organ console, or what-have-you on the stage, or it may be in a room off from the main room where the broadcast is to take place. It is usually tagged with an identifying card such as "WIRE Broadcast."

Since the problem of good transmission of talks or speeches at remote points is not nearly so difficult as that of musical pickups, the discussion to follow will concern music. Musical programs may originate at such places as ballrooms, restaurants, night clubs, and cafes featuring dinner music, and music for dancing and floor shows. The situation calls for a decided difference in technique of technical production between studio and remote broadcasts.

In the ideal studio musical setup, only one microphone is used at sufficient distance, with the musical instruments grouped and positioned so as to blend into the proper balance at the microphone position. This procedure not only simplifies the problem of control, which always makes for a better effect, but also leaves the problem of orchestral balance in the conductor's hands where it rightfully belongs. Multiple microphone arrangement will place the maximum responsibility for balance of the various sections in the hands of the operator mixing the outputs of the various microphones.

At remote points, however, where so much activity such as dining or dancing occurs, microphones must be placed close to the musicians. This is inevitable since otherwise the background noise would result in a disagreeable hodge-podge of confusion. This close microphone arrangement calls for the use of more than one microphone to achieve the desired balance; otherwise the instruments closest to the microphone would dwarf the rest of the orchestra. Then the setup is divided into units of like instruments or combination of instruments, each unit being covered by a separate microphone so that the volume from each unit may be adjusted at the mixing panel to achieve the desired balance.

The practice has some advantages for remote-control pickups other than avoiding background noise. Acoustical conditions that might severely affect the broadcast are minimized to the fullest extent, since the ratio of any reflected sound to the original sound is small. Then too, although some loss of tonal brilliance results from close microphone arrangement, good instrumental definition is gained, which is important for dance broadcasts.

Symphony music and church broadcasts are different in this respect in that the audience is comparatively quiet, and the pickup may be treated more as a studio show by studying the acoustical conditions existing at the point of origin. This is discussed in a following chapter.

Chapter 9

REMOTE MUSICAL PICKUPS

AN OBSERVATION of Fig. 9-1 will reveal the principles involved for a typical dance orchestra broadcast. Insofar as the operator is concerned, this setup divides the orchestra into three separate units: microphone #1 for saxophone and clarinets; #2 for trumpets, trombones, and soloist; and #3 for string bass and piano. Microphone #3 is very handy for special emphasis of the rhythm section, or piano or string bass solo passages. It will be noted that when the trumpets are open, they are behind the trombones and caught on microphone #2; when muted, they step down ahead of the trombones and immediately in front of the microphone. Muted trumpets or trombones must be played with the muted bells very close to the face of the microphone. The same is true of any wind instrument upon which the player is producing subtones. The subtones of any wind instrument are just as low in volume, even though open-belled, as the softest muted instrument. This, then, calls for close co-operation between the conductor and his musicians and the engineer responsible for proper pickup. Many times, important solo "licks" of a particular passage may be lost by lack of co-ordination.

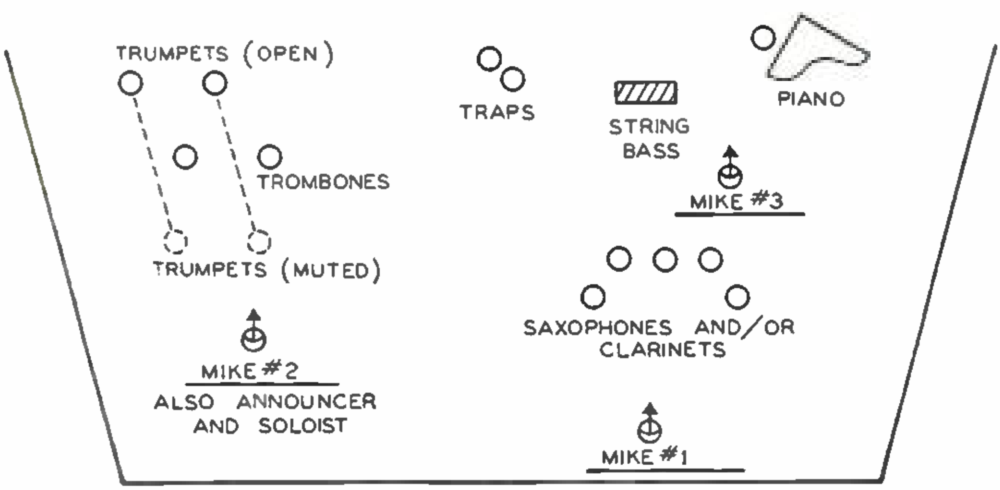


Fig. 9-1. Seating arrangement of dance orchestra and placement of microphones for a typical remote pickup.

Brass Bands

Although the 4/4 type bands share comparatively small time in radio, their particular peculiarities pose special problems in pickup. A number of community organizations, fraternal societies, and, of course, the armed services participate in radio through presentation of brass bands. These pickups very often must be made out of doors, the least favorable spot for broadcasting. With no outdoor shell or walls of any kind, no reflection of sound can occur to create the ideal polyphased sound dispersion so important to broadcasting technique. Under these conditions it is again necessary to use multiple microphone pickups, grouping the units by means of spotting separate microphones where needed as determined by trial.

For a fair-sized band organization, the units are usually as follows: one microphone for the clarinets, piccolos, and flutes; one for the English horns, bassoons, bass clarinets, saxophones, and tubas; and one for the French horns, trombones, and trumpets. The tympani, traps, and chimes are usually placed in the lower sensitivity zone of one of the microphones which prevents the use of excessive distance for proper balance. Indeed, the sensitivity pattern characteristics of the particular microphones used must be thoroughly understood for any kind of musical pickup. Tympani, when used with brass, are very predominate in character when placed in an equal sensitivity zone to the rest of the instruments. Just the opposite is true when they are used with strings, since the masking effect due to the characteristics of the musical instruments themselves tends to subordinate the tympani sound.

When well-designed outdoor shells are used, the ideal condition exists for brass-band broadcast. Usually only one microphone is used, suspended some 15 feet out and above the front-line musicians. As before, predominate instruments, such as tympani, traps, and chimes, are placed at the side in a lower sensitivity area of the microphone.

Salon Orchestra Remotes

Some dining places have salon or chamber music organizations which are picked up for broadcasting during the noon or early evening hours. Since a salon orchestra's library concerns the more serious type of music with many low passages, precautions must be taken to subdue as much as possible the noise of the patrons. An intimate microphone placement is therefore indicated.

Usually the salon group is small, ranging from string trios and quartets to about ten members. For the smaller groups, one microphone raised quite high and slanted down at an angle of about 35 to 45 degrees with the floor will be adequate. A hard floor with no covering will aid in obtaining just the amount of brilliance necessary for this type of pickup. A salon orchestra requires more definition than brilliance in musical tones.

Symphonic Pickups

Symphony orchestra programs have become a regular feature on the air each season and quite often must be broadcast from a remote point rather than from a regular broadcast studio. Thus far, musical setups have been discussed involving a comparatively small number of musicians and a specific type of instrumental structure. The symphony orchestra, however, is many orchestras in one. The engineer is concerned with the proper grouping of four distinct instrumental sections:

1. *Strings:* violins, violas, cellos, string basses.
2. *Woodwinds:* clarinets, bassoons, English horns, flutes.
3. *Brasses:* trumpets, trombones, French horns, tubas, euphonium.
4. *Percussions:* snare drums, bass drums, tambourines, triangles, cymbals, piano, harp, xylophones, marimbas, tympani.

To this instrumental setup, vocal soloists and choirs are often added, as for Beethoven's "Ninth Symphony" or Verdi's "Requiem." The musical score itself will influence many times the necessary spotting of microphones. For such numbers as the delicate "Clair de Lune" of Debussy, the perspective of the violin passages should be distant, with a rich and brilliant tonal quality. In numbers such as the Strauss waltzes, the perspective of the strings should be closer and more strident in character. This problem will be outlined in more detail presently.

As a general rule, the arrangement of the symphony orchestra for broadcast is the same as for a regular audience performance. The instruments vary in volume of sound produced and therefore in penetrative quality. Strings produce the least volume, then flutes, clarinets, horns, trumpets, and percussion instruments.

The acoustical situation for symphony broadcasts is generally better than for most other remote controls since the auditorium is usually designed for such large groups and made compatible with good listening for the audience, although not always ideal for broadcasting.

It is easier from a good transmission standpoint to encounter an auditorium that is too "live" and reverberant so that wall, ceiling, and floor treatments may be added, than to start from one that is too "dead" to sound reflection.

The correct setup for a symphony orchestra is always arrived at on the first rehearsal by trial and error. A number of microphones are spotted at the most likely points so that each may be tried without the commotion of continually moving one microphone. The most likely setup is one microphone suspended at a height of about 15 feet about 20 feet in front of the violins. A separate microphone must be used for vocal solos, since a closer relationship of vocalist to microphone must prevail for proper balance.

A typical setup for a full symphony orchestra was shown in Fig. 4-7 and no difference need occur for remotes. Some deviations occur in practice with various symphony orchestras. Toscanini's NBC pickup, which originates in a regular studio, uses two microphones for the main orchestra. Due to the directional characteristics and angle of placement (one for each side section), the orchestra is effectively divided into two microphone fields with little overlapping. Sometimes another microphone is suspended directly over the violin section for special effects on certain compositions as mentioned before. The Ford Sunday Evening Hour, broadcasted over CBS on Sunday evenings, used two microphones on the choir for clarity and definition of diction.

In chapter 11 is a complete description of a specific symphony setup.

Church Remotes

Programs from churches usually involve both music and the sermon.

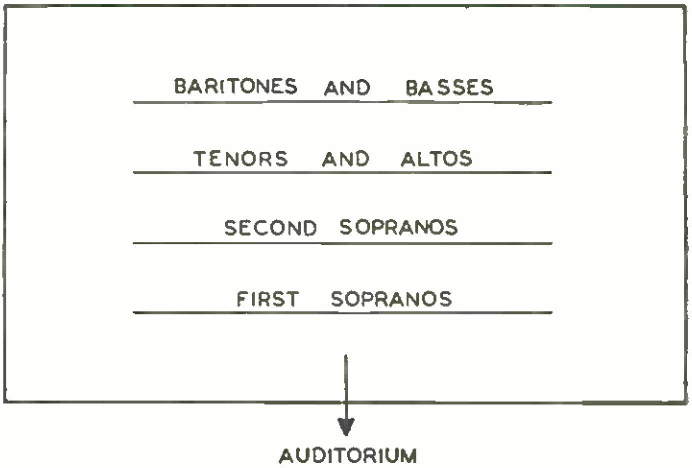


Fig. 9-2. The usual positions of a choir as shown here, results in too strong soprano response and insufficient alto and bass. Compare Fig. 9-3.

This ordinarily requires only one microphone when the minister's podium is directly in front of the choir as is the most common church arrangement. When vocal solos occur during the choral rendition, a separate microphone is necessary for proper pickup and balance. It will be noted in nearly all instances that, during solos being picked up by a microphone very close to the choir loft, organ accompaniment must be brought up to the proper background level by use of the rostrum microphone or microphone farther out in the congregation. This is due to the acoustical properties which are evident in nearly all churches causing the organ tones to be much more predominant out in the congregation than up near the choir.

Conventional choir arrangements are often not practical for broadcasting whether in a regular studio or at a remote point. Fig. 9-2 illustrates the usual arrangement of a choir as used for auditorium or church presentation. On a broadcast, this arrangement nearly always results in a predominance of soprano voices with very little alto or bass. Fig. 9-3 shows an arrangement much more satisfactory for broadcast purposes, resulting in a better all-around balance of voices.

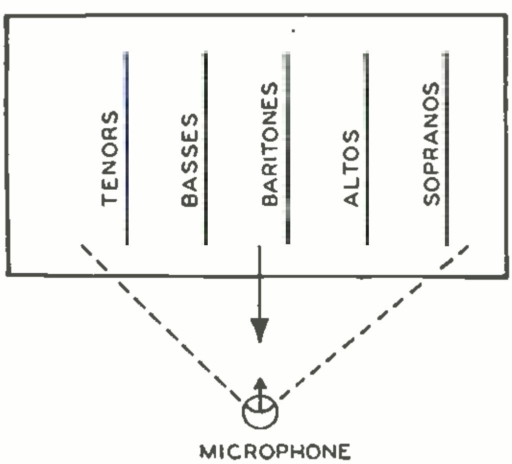


Fig. 9-3. By placing a microphone in this relationship to the rows of singers, a better all-around balance of voices is obtained over the arrangement shown in Fig. 9-2.

Although it would be impossible to cover all the details and complexities of remote-control pickups in a single discussion, it is hoped that the picture here presented has set forth the fundamental procedures that would help in a general way to approach a remote-control problem properly. To present an absolutely complete picture would be impossible, since acoustical conditions and orchestral intent varies as the number of places from which a broadcast can originate, and the number of different musical combinations existing. A good understanding of equipment and acoustical variations, however, will enable any engineer to achieve good results on this type broadcast.

Chapter 10

EYE-WITNESS PICKUPS AND MOBILE TRANSMITTERS

THERE ARE many types of events of wide public appeal that cannot be adequately covered by the usual methods of remote-control pickups using wire lines for links of communication. Among these are various kinds of sports such as boat racing, cross-country events, and golf matches. Aside from these events, there are the inevitable times of disaster such as floods, fires, earthquakes, and the myriad types of catastrophes that wreck ordinary communication services for many miles around the point of trouble. In order to be prepared to bring eye-witness accounts of happenings of these kinds to

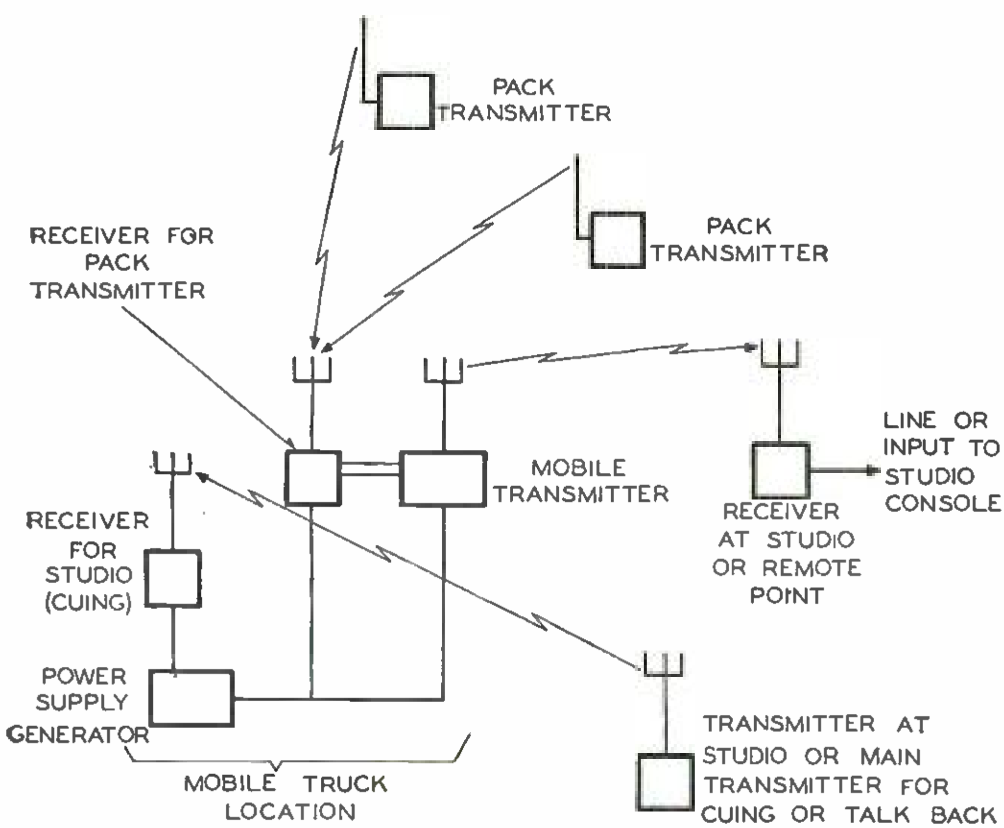


Fig. 10-1. Block diagram of equipment for pack-to-truck and truck-to-main transmitter relay transmissions.

NBC Photo

Fig. 10-2. Broadcasting an eye-witness account of the burning of the S.S. Normandie from an adjacent pier by means of a pack transmitter.

the thousands of interested listeners, most stations are equipped with portable and mobile relay facilities that utilize power supplies independent of utility companies, and also independent of any necessary wire lines, for relaying the signal to the studio or main transmitter.

There is probably no other division of radiobroadcasting that differs so radically from one station to another as the mobile-relay department. Fundamentally, however, the necessary inventory of equipment includes small portable transmitters known as "pack transmitters," a mobile transmitter and antenna mounted in a truck, receivers for cuing and pickup of pack transmitters, and power supplies for the equipment used.

Fig. 10-1 shows the fundamental layout of equipment used to broadcast any event as mentioned in the beginning of this chapter. Pack transmitters are low-output transmitters (usually about 2 watts) such as illustrated in Fig. 10-2. These transmitters are usually good for line-of-sight transmission only and therefore are picked up on a receiver in the mobile truck and fed to the main mobile transmitter. Mobile transmitters with their associated antenna systems are mounted in trucks or cars, such as that illustrated in Fig. 10-3.

Frequency Assignments

A license issued to a broadcasting station for mobile relay purposes covers a group of four frequencies as follows:

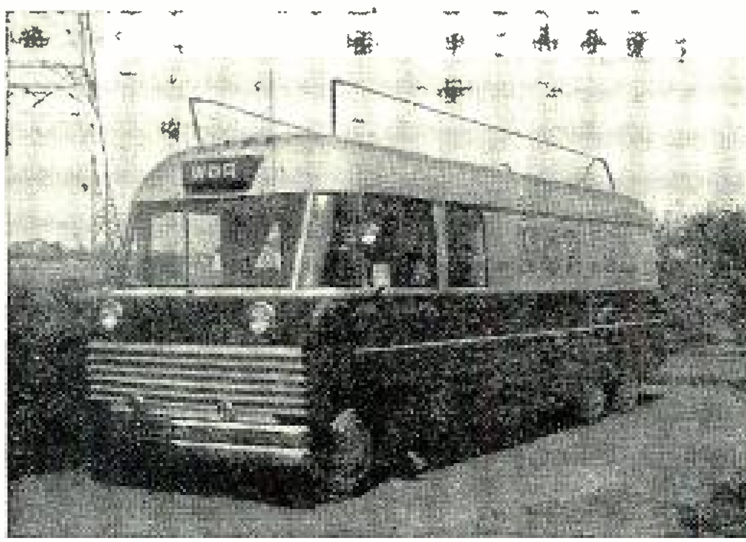
Group A (Kilocycles)	Group F (Kilocycles)
1622	31,620
2058	35,260
2150	37,340
2790	39,620
Group B (Kilocycles)	Group G (Kilocycles)
1606	33,380
2074	35,020
2102	37,620
2758	39,820
Group C (Kilocycles)	Group H (Kilocycles)
1646	156,075
2090	157, 575
2190	159,975
2830	161,925
Group D (Kilocycles)	Group I (Kilocycles)
30,820	156,750
33,740	158,400
35,820	159,300
39,980	161,100
Group E (Kilocycles)	Group J
31,220	Any 4 frequencies above
35,620	300,000 kc *excluding* band
37,020	400,000 to 401,000 kc.
39,260	

Only one of any of these groups is assigned to each station. In order to avoid interference problems insofar as is practically possible, the FCC (Federal Communications Commission) has ordered that the first application from any particular metropolitan area in groups *A*, *B*, or *C* shall specify group *A*, the second shall specify group *B*, the third group *C*, the fourth group *A* again, etc. The same is true of groups *D*, *E*, *F*, or *G*.

Group *H* is assigned only when need for these frequencies may be shown. Group *I* is for frequency modulation only. Group *J* is issued only to stations capable of carrying out research and experimental work for advancement of relay broadcast services.

Operation

Relay stations in groups *A*, *B*, *C*, and *J* are licensed to operate with a power output no more than is necessary to receive the signal satisfactorily. Those in groups *D*, *E*, *F*, and *G* are not licensed for an out-



WOR Photo

Fig. 10-3. The second link in an on-the-spot broadcast is often a mobile short-wave transmitter installed in a truck.

put power in excess of 100 watts. The FCC also stipulates that before any power in excess of 25 watts is used, tests shall be run to insure that no interference will occur to the service of any government station.

A station with only one license may use only one of the four authorized frequencies at any one time. When it is desired to transmit the program on one of these frequencies and maintain contact with the studio on one or more of the other authorized frequencies at the same time (such as for cuing purposes and instructions), two or more licenses must be obtained by the station.

The operator of a relay broadcast station must maintain the frequency of the transmitter within the following limits:

(a) 1622 to 2830 kc: within 0.04%
(b) 30,000 to 40,000 kc and above: 10 watts or less within 0.1%, over 10 watts within 0.05%

The operator must also be certain that the call letters of the relay station are announced at the beginning and end of each period of operation (whether rebroadcast on the main station transmitter or not) and at least once every hour during the operating period.

Chapter 11

THE LIVE SYMPHONY PICKUP

By Bert H. Koeblitz

Most operators will probably never be called upon to handle a live symphony program. This is because the proportion of symphony programs to all the programs broadcasted is very small, and when a technician has handled such an event well he is likely to be used over and over again for this work. In other words, such a job is not "passed around" to give everyone a chance at it as is the case with many other things. No one knows, however, when he may be given a chance to handle such a program, in which case a little inside knowledge will be of great value. The information is not lost in any case, because almost every fundamental point in symphony handling is applicable to other types of programs. A great deal of symphony technique can be used to advantage in recorded symphony programs.

Making a symphony pickup involves numerous problems, some of which are technical and some which are not. Some of these problems are psychological, some social, others political. Hence, not only the technician, but representatives from all departments of the station staff may be called upon at times to effect a solution. You are probably wondering why this should be mentioned in an operators' handbook. At WHK it is standard practice to have the technician attend all rehearsals to get a reading on various orchestral numbers. Usually he is the only station representative present and so may be called upon to handle details outside his own department; therefore it is well for him to know the activities of all departments.

The symphony management perhaps has to be convinced that the broadcasts will be beneficial to it and that they will be properly handled by the radio station and its staff. The attitude of the conductor and the assistant conductor to the broadcast will make the situation easier or more difficult, as the case may be. The acoustical characteristics of the hall in which the orchestra plays will govern the limits of what the technician can do to make a good pickup. The type of microphone, the number of them used, the associated equipment, especially the monitoring facilities, will all affect the pickup. Finally, the technician who handles the faders can make or break the program. Perhaps the best method of getting detail on all these things would be to describe how these problems were handled by WHK in its broadcasts of the Cleveland Symphony Orchestra to the Mutual Network.

Pre-Broadcast Problems

Early in 1943, Mutual decided to furnish its listeners with a complete season of Cleveland Symphony broadcasts, if suitable arrangements could be made with the orchestra management. These arrangements, for the most part, were made by WHK personnel with the cooperation and guidance of Mutual's president. The first and probably the greatest obstacle which had to be overcome was the symphony management's fear of hurting box office receipts, which fear seems to have been quite common in the past. A symphony orchestra has a great many musicians in it. If the orchestra is to be really good, there must be a fair proportion of the country's better musicians in it. This costs money. It was feared that a weekly radiobroadcast would tend to keep people from coming to the regular concerts, which would result in a smaller income and eventually would reduce the caliber of men in the orchestra.

WHK was firmly convinced that such an impression was erroneous and was finally able to get the symphony management to agree to let Mutual hire the orchestra for a one-hour program each week. It was agreed that the major work presented on the broadcast would never be the same as the one performed at the Thursday and Saturday evening regular concerts. Thus no one could hear a major work played over the radio which someone else had to pay to hear. Before the season was half over, the box office had exceeded its record for any previous year since the orchestra had started. WHK feels, therefore, that the broadcasts not only did not hurt the box office receipts, but actually increased them to these unheard of proportions.

Once the business arrangements with the symphony management had been completed there remained about a month's work to co-ordinate all the other factors before the first program was broadcasted. Those factors included orchestra conductor, associate conductor, radio script, orchestra seating, auditorium acoustics, announcer, technicians, microphone types and placement, and monitoring facilities.

The conductor during the first season of broadcasts was Erich

Leinsdorf who had been conducting Wagner for the Metropolitan Opera Company. Despite his comparative youth, Mr. Leinsdorf had a wealth of conducting experience and was a most thorough all-around musician. He was extremely conscientious about respecting the composer's wishes rather than giving his own interpretation of the composer's ideas. He was enthusiastic about the broadcasts and helped greatly with accurate timing and correcting minor unbalances in the orchestra. The associate conductor was Dr. Rudolph Ringwall, who also is a first-rate musician and conductor. Dr. Ringwall was not only enthusiastic about the broadcasts, but was experienced in these matters and therefore understood most of the problems. His experience in both music and radio proved to be of inestimable value in making the original setup and in properly presenting the orchestral works later. On every program which he did not conduct he was in the monitoring room with a score, telling the technicians in advance what they might expect at various places.

The orchestra management was somewhat concerned over the program notes to be used on the broadcasts. It was certain that the notes should be written by someone with a good knowledge of orchestras and classic works, and it was equally certain that the broadcast had to be timed out properly. This was worked out by two people. There was no doubt that the person best qualified to write the program notes was the program annotator of the Cleveland Orchestra. There was also no doubt that the radio production man should control the timing. So, early in the week, the orchestra would rehearse the radio numbers so that they could be timed. Once the total music time was known, the program annotator could be told how much script to write. This would not give the desired effect, however, because the announcer might have read at a different speed than the annotator had expected and musicians and conductors vary their tempos with weather, auditorium acoustics, audience reaction, and their personal feelings.

To overcome this difficulty, articulated copy was used. The annotator wrote solid copy which would last two minutes less than the time at his disposal. Then he would add to the middle and closing announcements several paragraphs of 15 or 20 seconds duration which could be used or not. The closing announcement was written in four parts in such a way that any part or any combination of parts made a complete sign-off. These four parts were 1½ minutes, 1 minute, 30 seconds, and 15 seconds long so that the announcer could adjust the closing to take anywhere from 15 seconds to 3¼ minutes. This system was highly successful because no deletion or padding was ever apparent to the listening audience, and hurrying or slowing down the talking speed was never necessary.

Physical Arrangement of Orchestra

The physical arrangement of the orchestra is a matter over which the radio station has little control. Each conductor has his own preferred way of placing the men, and if there are to be any guest conductors, the radio people are faced with the problem of constantly changing setups. At least so it would seem. As it worked out in practice with the Cleveland Orchestra broadcasts, no change of microphone position was necessary with rearrangement of orchestra personnel. The seating arrangement used by the regular conductor of the Cleveland Orchestra was highly recommended from both practical and theoretical points of view.

The strings were placed in rows which radiated like spokes from the conductor's podium back to the last riser. As the conductor faced the orchestra, the first few rows to his left were first violins and the next few rows were second violins. The principal sound from a stringed instrument radiates on a perpendicular to the belly. With the microphone placed above and directly behind the conductor, the violins were in perfect position for optimum results. To the conductor's right were violas and cellos in rows like the violins. Here it might be argued that in theory the violas and cellos were in a poor position, since their sound holes would point away from the microphone. In practice this arrangement proved to be satisfactory because these instruments have a slightly more robust tone than the violins and normally are a supporting rather than a lead voice. The cellos, which are often a weak section, had a direct line to the microphone and picked up beautifully. The strings mentioned so far roughly form a shallow letter "V" with the conductor at the vertex. The front part of the remaining empty space seats the woodwinds, not in spoke-like rows but as arcs of circles with the conductor at the center. Behind them were trumpets and trombones. Still farther back and constituting the last row were the bass viols. To the left of the basses were the French horns and tuba and to the right were tympani and percussion. The harps were on the top riser back of the violas. When the guest conductors changed everything around, it was discovered that, within reasonable limits, there was no difference in the pickup no matter how the orchestra was placed. This possibly was because of the excellently designed shell around the stage at Severance Hall.

The acoustics of the hall in which the orchestra plays will have much to do with the microphone setup. A "live" hall is preferred by a good many symphony listeners. Such a place need not be of undue concern to the technician unless there is a bad reflective path coming back to the stage. This can be tested initially by clapping the hands while standing on the stage. If the noise reverberates but dies off, you have nothing to worry about. If a second hard slap comes back, then you have troubles. There is one hall in the United States that is so poor acoustically that a curtain has to be hung between the stage and the auditorium when the orchestra rehearses in order to keep reflected notes from interfering. Severance Hall in Cleveland has excellent acoustics. A person speaking with ordinary volume on the stage can be heard in every seat in the house without the use of a public address system. Another striking fact about this auditorium is that the acoustics are the same whether it is empty or full. This is because the seats are upholstered and covered with plush, thereby absorbing sound just the same as clothing does.

The selection of a suitable announcer does not concern the technical department except that the technician should exert whatever influence he can to see that this man has a moderately deep and pleasing voice and has a little knowledge of what he is talking about. The selection of technicians for a symphony broadcast should be made carefully. At WHK, there are several different groups in the technical department. Men are not specifically assigned to any one group, but each more or less gravitates toward his major ability and preference. There are studio control men, master control men, remote pickup men (usually studio men with extra ingenuity), maintenance men (who also build new equipment), transmitter operators, and development engineers. It was decided by the executives to send two technicians out, since all the equipment was in duplicate. It so happened that the best studio control man, who was also the best remote man, liked symphony music, so he was selected to make the setup and push faders on the program. One of the maintenance men, who was an excellent mechanic and trouble shooter, also liked symphony music, so he was sent along to provide whatever facilities the other man might require. Selection of microphones is a matter of station facilities, individual auditorium characteristics, and personal preference. Monitoring equipment should be the best obtainable and in no case inferior to the line you are feeding.

Microphone Placement

It is perhaps just as important to know what not to do as to know what to do in certain instances. Therefore the whole process of arriving at a microphone placement will be described. In some auditorium other than Severance Hall, the things discarded might have been retained. An all-around picture will give a clue to procedures possible in any hall. To begin with, the two technicians agreed beforehand that the pickup should be made with a single microphone. To use more than one would take the problem of orchestral balance from the conductor, where it properly belongs, and make it the responsibility of the technician, who nine times out of ten would garble it. The conductor and the associate conductor were persuaded on this basis that one microphone would be best and that it should be placed somewhere on the direct-center stage line. Three 1-inch brass angle brackets were made up to suspend three microphones each. Armed with these brackets, nine microphones, and a bushel of clothes line, in addition to the regular remote equipment, the two technicians arrived at Severance Hall three hours before rehearsal time.

Before anything else was done, a height of 15 feet above stage level was agreed on for the position of the microphone. The first bracket was hung 15 feet high and about six feet into the orchestra from the conductor's position. It supported a Western Electric 618-A dynamic microphone, an RCA ribbon strapped for voice, and a Western Electric cardioid set on cardioid. The second bracket was directly over the conductor and supported an unbaffled eight-ball microphone, a ribbon strapped for music, and a cardioid. The third bracket was about six feet behind the conductor and contained an unbaffled salt-shaker microphone, a ribbon strapped for voice, and a cardioid. Extension cords were run into a monitoring room and arrangements made to listen to each microphone separately.

By this time the stage began to look as though we were preparing for a circus performance. The conductor went through his rehearsal just as if nothing were amiss, while the associate conductor and technicians selected a microphone. It is useless to recount the endless discussions and ladder climbing; therefore only the results will be given. First it was determined that the first and second bracket arrangements were too far forward to give sectional balance to the orchestra.

In either of these positions some group of musicians dominated beyond all proportion over the volume of the rest. The third bracket arrangement was shifted back and forth until all were satisfied that the orchestra sections were balanced. This satisfactory position was 12 feet from a line drawn across the stage just touching the chairs of the musicians closest to the audience. During intermission, all three bracket arrangements were clustered together so that all the microphones could be tried.

The results of this experiment were as follows. The 618-A dynamic microphone had sufficient "highs" but not enough bass. Also, the "highs" were spotty, certain high frequencies being accentuated more than others. Both the unbaffled eight-ball and the unbaffled salt-shaker microphones gave excellent reproduction and were thought by the technicians to be satisfactory. However, the "highs" were reproduced so well that a considerable amount of extraneous noise such as bowing rasp and reed sizzle were noticed. While this was *faithful* reproduction, it was not *pleasant* reproduction. The ribbon strapped either way did not even approach satisfactory fidelity. Since the cardioid gave splendid reproduction without accentuating the extraneous noises, it was selected and it also had the virtue of wide-angle frontal pickup and was electrically "dead" toward the audience. In practice, a stand was used instead of the trapeze, two units being mounted side by side with one for regular use and one for emergency use. This may be summarized as follows: the pickup should be made with a single microphone. That microphone should be somewhere on a line at the direct center of the stage. In Severance Hall a Western Electric cardioid set on cardioid was used, 12 feet toward the audience from the nearest musician, 15 feet above stage level, and tilted to point approximately at the center of the orchestra.

Other Problems

The amplifier following the microphone was flat to plus or minus 0.75 db from 30 to 15,000 cycles. One of its 500-ohm outputs was fed to a 111-C coil strapped 1-to-1, which in turn fed the phonograph input of a speaker amplifier. The speaker amplifier was a high-fidelity type with separate bass and treble tone controls arranged so that in the middle position for each one the amplifier was flat. This in turn fed a high-fidelity speaker. The room containing this equipment was about 20 by 30 feet and was furnished much like a living room. Those are important considerations—the size of the room and the furnishings.

The best speaker in the world is ineffectual in a small room, and a room that is too live will tend to cause the technician to reduce the "highs." The speaker was placed at one end of the room and the technician at the other so that the tones had a chance to develop and blend before he heard them.

The next step was to set the speaker volume properly. It is well known that the efficiency of the ear varies with volume intensity; therefore some standard had to be set up which could always be used—in this case something in the nature of a hike. The two technicians and the associate conductor tried seats in every section of the auditorium and finally agreed that the orchestra sounded best in the middle seats of the 8th, 9th, and 10th rows of the middle section on the main floor. These seats are directly in line with the microphone. After a multitude of trips from the seats to the monitoring room, the volume on the speaker was fixed so that the same level came to the control position as was noticed in the referenced seats. Fortunately, the speaker amplifier had a volume indicator on it so that this volume could always be maintained regardless of tube wear.

Once the mechanical equipment is properly arranged, there remains the problem of properly broadcasting the program. A psychological reaction is strongly involved in this procedure. The most common complaint from musicians and conductors is that the technician raises the soft passages and reduces the loud passages, thereby defeating the function of the conductor and destroying the symphonic intent of the music. It is therefore mandatory that some procedure be used which will insure at least the approximate dynamic range of the orchestra in the hall. The upper limit is, of course, the maximum operating level of the particular station involved. The lower limit is the signal-to-noise ratio at the receiver location. Inside the primary service area of a station there is normally no difficulty with signal-to-noise ratio. If the soft passages are raised to help the listeners outside the primary service area, the loud passages, of necessity, will have to be reduced. In that case no listeners in *either* area are able to enjoy the full dynamic range. If the soft passages are not raised, the listeners inside the primary service area can be given the full dynamic range of the orchestra.

At WHK it was decided that it was better to serve *some* listeners well, even at the expense of others, than to serve *no* listeners well. One of the technicians assigned to the symphony was sent to all rehearsals. He set up the equipment just as he would for the actual broadcast.

Then he would arrive at a fader setting for each number or movement which would cause the vu meter to peak no more than the maximum allowed. These settings were carefully written down so that on the evening of the broadcast the orchestra fader was always set at the correct place before each number started and was never moved during the number. Thus listeners were furnished with the full dynamic range of the symphony orchestra.

This proved to be only part of the total problem. Using the method just described will mean that the listener has to increase the setting of the volume control on his set if he desires to hear the softest passages. If the listener does this (and he will if he is a symphony enthusiast), the level normally permitted announcers will drive him out of the room. Therefore it is necessary to keep the announcer's level somewhat below standard.

The easiest way to state the comparative readings is in per cent. If the maximum peak allowed the orchestra is 100%, then the maximum peak allowed the announcer should be 40%. Later in the season it was discovered that this procedure resulted in a sort of automatic set tuning action. The symphony programs from WHK always were introduced by the announcer. Normally, the listener already had his set turned on listening to some other program. When the symphony announcer came on peaking only 40%, his voice would sound much too soft so that the listener would increase the volume until the announcer's voice sounded normal. This usually proved to be approximately the correct volume for symphony listening.

The Soloist Microphone

The last important consideration in symphonic pickups is the presentation of soloists. In a way, the term "soloist" is erroneously interpreted, especially where it pertains to instruments. Most of the compositions written for this type of presentation are either concertos or in concerto form. In a concerto, the solo instrument is no more important than any other voice in the orchestra. One has only to listen to air presentations of such performances to realize that this fact is generally ignored. About half of the time in an ordinary concerto the orchestra is supposed to take precedence over the so-called soloist. It is not only a matter of relative volume but also includes the delicate distinction of relative auditory presence.

For example, a trumpeter three feet from the microphone can blow softly enough so that he will produce a tone of the same electrical volume as a trumpeter ten feet from the microphone blowing a little louder. Yet the two tones will not sound the same. Why? Actually there are two reasons; the first of which is that a trumpet does not sound the same when it is blown softly as when it is blown loudly. That variable can be eliminated. Let the two trumpeters keep the same distances mentioned and both blow at exactly the same volume. Then the technician can adjust his fader so that they will both register the same electrical volume; however, they still will not sound alike. That is because their auditory presences are different. Therefore, to present a soloist properly with an orchestra in a concerto, it is necessary to place the solo microphone far enough away so that the auditory presence of the soloist *regardless of volume* is the same as that of the orchestra.

There is no rule of thumb on how to accomplish this since the relative distances will vary with auditoriums. It has to be done by trial and error during rehearsal; also, the distance will rarely be the same for two different performers. Once the distance is established for a given performer, the microphone fader must be carried only high enough to give a small amount of definition to the instrument. If the solo volume is allowed to go to 100%, it has the same effect as allowing the announcer to peak 100%.

Transporting Equipment

There is one other consideration peculiar to the Cleveland Orchestra that may not obtain in other cities. The experience gained, however, has sufficient application in ordinary remote work to bear relating. The Cleveland Orchestra makes three concert tours each year, which means that five broadcasts will be in some city other than Cleveland. Since so much care had been taken to insure a good pickup locally, and since so much depended on the particular technicians assigned and on the particular equipment used, WHK decided to take precautionary measures and send those men and that equipment along. Transportation for the men was no problem, but there were 800 pounds of equipment that could not be condensed into a small shipping case. Like Noah, it was decided to take two of everything.

There were no standard trunks, sample cases, piano boxes, etc., which would satisfactorily hold the equipment. An old trunkmaker was found who agreed to build trunks especially for the equipment. Accordingly, he was provided with a complete duplicate set of equipment. Two months later it was returned to WHK enclosed in two

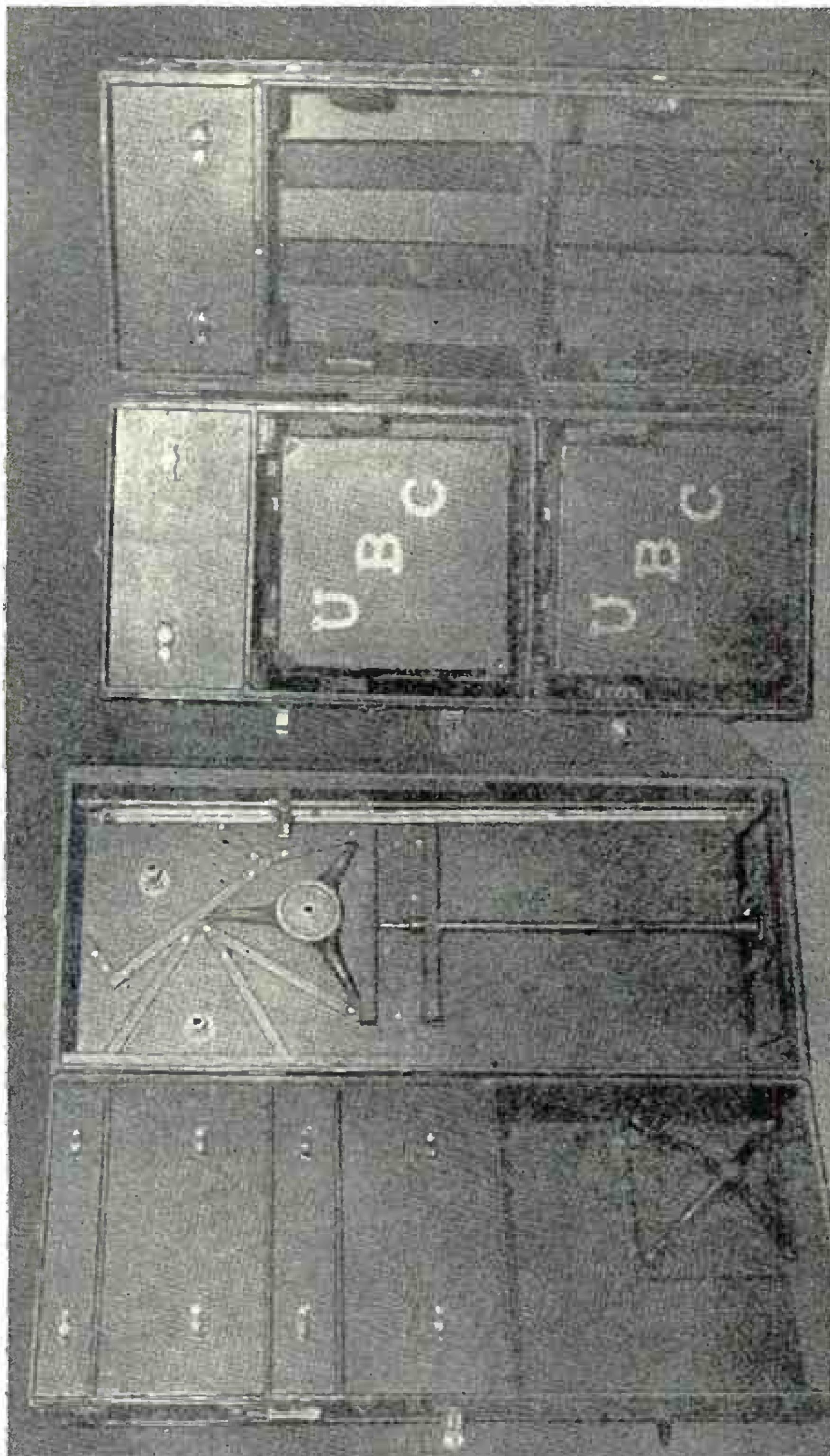


Fig. 11-1. The larger trunk on the left accommodates the microphones, their stands, extension cords, tools, etc. The second trunk is designed for two remote amplifiers and battery boxes.

trunks, as shown in Fig. 11-1—trunks an expressman would consider ideal to handle. The trunkmaker had done an ideal piece of work on them because not a single piece of equipment has been damaged in two years of travel, and on more than one occasion the trunks were delivered in a distant city by one man, which meant they were dropped off the truck and rolled end over end into the auditorium.

The larger trunk is for microphones and stands. The microphone heads are removed and placed in drawers which have compartments lined with two inches of sponge rubber and fitted with tops, so that when the drawers are closed nothing can move. The other half of the trunk is devoted to an arrangement for solidly holding microphone stand bases and shanks. There are two extra drawers for extension cords and tools. The smaller is arranged to accommodate two remote amplifiers and two battery boxes. One set fits into each side in sponge-rubber-lined compartments. There are also two extra drawers for miscellaneous use.

To assure its delivery for the orchestra broadcasts on Sunday, the equipment is sent to the distant city on the previous Monday. The technicians arrive there either Thursday evening or Friday morning apparently early for a Sunday broadcast, but for a good reason. The telephone companies usually terminate the lines somewhere on the stage unless a specific place is requested; however, the technicians prefer to work in a separate room beyond the stage. Because most auditoriums are devoid of help from Friday night until concert time on Sunday, the technicians, by arriving at that earlier date, are assured of having their individual room.

Problems of Strange Auditoriums

Another interesting problem arises in working in a strange auditorium. All auditoriums are different and there is no possibility of rehearsal because the orchestra does not usually arrive in the broadcast city until two or three hours before concert time. First, the technician should stand on the stage and clap his hands in a hopeful effort to ascertain the acoustics of the hall. From what he hears, he tries to determine how much that will change with an audience; however, he does not have to be too particular. If the original clap echoes but dies away, the pickup will be live but not distorted. If the sound of the original clap is returned as though the hands were clapped twice, then something has to be done. If a cardioid microphone is used, it can be placed with no tilt and lowered about three feet from its normal position. This places the dead side directly toward the clap and the reduced height partially restores any loss of balance resulting from no tilt. Sectional balance would be difficult in such a live hall anyway. The main problem is to get whatever sound is reproduced as clear as possible.

Another problem is presented by the variety of stage sizes and shapes in different auditoriums. In some the stage will be very wide but very shallow, making it necessary for the orchestra to be in a long narrow rectangular arrangement instead of a semicircular arrangement. In such a case the microphone can be tilted almost to a horizontal position in order to diminish the pickup of wind instruments. The strings will be physically farther from the microphone in this instance so it will be necessary to keep the wind instruments down. Another type of stage which gives trouble is one without any shell where a great deal of the sound is not projected forward. The solution is to leave the microphone at normal tilt but lowered a couple of feet and moved in closer to the conductor.

The final consideration on road trips is difference in level from the home auditorium. A fader setting noted at rehearsal in the regular hall will not necessarily pertain in some other hall. A live hall with a shell is likely to give more deflection than expected, and a hall with no shell is likely to give less. Unfortunately no indication can be had from the announcer's voice since he is working so close to the microphone that acoustics have little if any bearing on his level. The safest way is for the orchestra fader to be set where it would be in the home auditorium. If the level is too high, the fader should be reduced *one* notch *after* each group of excessive peaks. By the time that particular number or movement is completed, the normal level should be determined for that auditorium. The amount reduced can then be subtracted from all fader settings marked down for the other numbers, eliminating any further guesswork. If the level is too low, as compared to the local hall, the fader should be increased one point each time a climax, remembered from rehearsal, fails to peak 100%. The difference thus arrived at can then be added to the other settings.

To sum up the symphony broadcast,

1. A single microphone should be used behind the conductor on a line with center stage and uplifted in the air (usually about half the height of the proscenium arch).

2. Auditory presence should be adjusted for soloists without giving them too much volume.
3. Fader settings should be determined at rehearsal and not changed on the broadcast. Where this is impossible, faders should be moved very gradually to obtain proper setting.
4. The best possible equipment should be used. The setup depends upon what is heard through that equipment.
5. The symphony broadcast technician should be prepared to argue with his fellow workers and A. T. & T. about low level. But be firm, because they will give up in five or six weeks.

Part 4

OPERATING THE TRANSMITTER

Chapter 12

OPERATOR'S DUTIES

ALL ENGINEERS and students familiar with the technical characteristics of transmitting equipment in general, and broadcast equipment in particular, are cognizant of the greatly advanced state of technical design and transmission fidelity. It will not be the purpose of this section to duplicate the already published data on broadcast transmitter circuit theory and relationships. A workable knowledge of this field is assumed in this text.

The discussion to follow will pertain to the all-important operation of the broadcast transmitting installation in order to achieve the best results possible from the finely engineered equipment available and in use today. Operating practice at the transmitter is just as important in the final result of over-all performance as it is at the broadcast studio. The science of operating the transmitter and associated speech input equipment may be shown to be a highly specialized art, and we have chosen the term "operational engineering" to define the content of the special study undertaken in this part of the handbook.

Outline of Responsibilities

It is true that the primary purpose of the transmitter operator is *to keep the station on the air.* But with the rapidly progressing demands for higher-fidelity program transmission, the day when the typical "ship operator" of thorough technical understanding could step into a broadcast installation, has passed forever. The operator of a broadcast transmitting plant has a specialized range of duties requiring a technical education, plus a thorough understanding and appreciation of the more intangible values of program material.

A number of his fundamental duties are, of course, strictly technical in nature and, since this is meant to be an analysis of an operator's duties, the technical functions will be described from an operational point of view. In brief, his technical duties consist in turning the transmitter on ahead of the beginning of the daily program schedule, checking all meter readings to make proper adjustments, checking level with the studio, shutting down the transmitter after sign-off, repairing and maintaining equipment, and testing for noise and distortion levels. During the daily operating schedule he consistently monitors the program from a monitoring amplifier and loudspeaker, adjusts line amplifier gain in accordance with good engineering practice pertaining to percentage modulation (the transmitter operator does not normally "ride gain" as does the studio operator), maintains correct tuning of transmitter, logs all meter readings every 30 minutes required by the FCC, and corrects any trouble that develops in the shortest possible time. Useful hints for meeting technical emergencies will be given later.

Typical Pre-Sign-on Procedures

The transmitter operator in all but the lowest power local stations is usually scheduled to be on duty at least 30 minutes prior to air time for the purpose of getting the equipment ready for the broadcast day. The start of an operator's day may be outlined as follows:

1. Audio rack power applied (including such measuring equipment as the frequency monitor and modulation monitor). Audio line used as program loop opened by inserting patch cord into the line jacks. This removes the line from the input to the line amplifier and prevents any test program that might be on the line from the studio from being applied to the transmitter when turned on.
2. Visual inspection of all relays in antenna-phasing cabinets (where used) and in coupling houses at the antennas. Relay armatures manually operated to ascertain freedom of movement. Observation of pointers on all r-f meters for bent hands or zero set.
3. Inspection of all safety gaps including antenna and transmission-line lightning gaps for approximate correct spacings.
4. Water pumps started (where used) and rate-of-flow meters observed for correct rate of water flow. Water flow must be normal before filament voltage is applied. Air-cooling systems usually start the blower motors when "filament-on" switches are operated. Transmitter filaments now turned on and filament voltages checked. In large power tubes using tungsten type filaments, minimum voltage should first be applied, then run up to normal filament voltage after about 3 or 5 minutes.

This is a means of lengthening the usable life of such power tubes but it is not observed in some stations. Tubes of the thoriated-tungsten or oxide-coated filaments such as used in the low-power stages, are always operated at *normal* filament voltage for maximum tube life.

5. Plate voltage then applied to low-power units or exciter unit (in power installations of 1 kw or more) to check for proper excitation to final stage.
6. Low power then applied to final stage. All meter readings checked for normal low-power operation. If everything is normal, high power applied and meter readings checked.
7. Filament and line voltages checked and adjusted for high-power operation. Final adjustment made on final stage for optimum meter readings regarding resonance condition and power input.
8. Since the control-room operator sometimes has circuits "hot" with his own testing procedure, the transmitter operator plugs patch cord from program line to monitor amplifier to ascertain continuity of program line. Then notifies control operator to stand by for over-all circuit test. When this has been done, transmitter operator removes patch cord from jacks which automatically restores line connection to input of line amplifier. A test tone may then be fed from studio to check over-all continuity of circuits from studio to transmitter modulators.

Pre-Program Level Checks

Level checks with the studio are not required as a daily procedure after an initial installation has been made, tested, and operated for some time, since with properly operating equipment the level remains very nearly the same over a period of time. At regular intervals, however, it is desirable to use a signal generator to check the frequency characteristics of the line and transmitting equipment. In this connection it is well for the transmitter operator to understand the difference in modulator power requirements for sine wave and speech or music program content.

It will be remembered from circuit theory that for a class C modulated amplifier, the power requirement for complete *sinusoidal* modulation is 50% of the d-c power input to the modulated tube or tubes. Fig. 12-1, however, shows how the "peak-factor" of speech or music waves varies greatly from that of a pure sine wave. This peak factor of program waves is 10 to 15 db *more* than that of a sine wave. That is, the ratio of peak to rms voltage is far greater for complex waveforms than that of a sine-wave form. In other words, the *average* power for complete modulation of a transmitter over a period of time is far less than the average power required for complete modulation by means of a signal generator. It is a well-known fact that for program

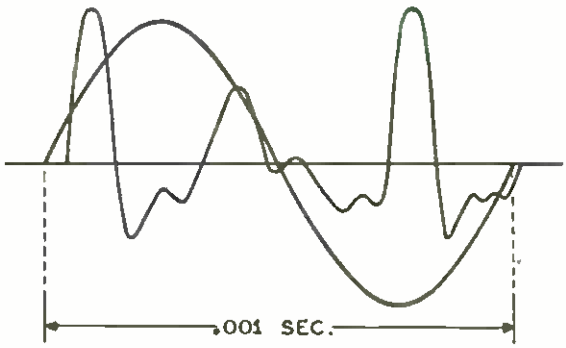


Fig. 12-1. The "peak factor" of a speech or music wave is 10 or 15 db greater than that of a sine wave; i.e. the ratio of peak to rms value is greater for complex waves than for sine waves.

signal waves the modulator power required may be 25% or less of the d-c power input to a class C stage. Therefore, if a signal generator is used at the studio for frequency runs or level checks, the transmitter operator must realize that if he has adjusted the gain on the line amplifier to give 100% modulation on sine wave, the same adjustment will be 10 to 15 db *high* for program signals. Thus the gain adjustment must be lowered to the point that experience has dictated for program modulation before the actual program schedule starts. In the past this has led to some confusion among transmitter operators.

This difference in peak factor between program and sine waves is also noticed when comparing the per cent of antenna-current increase with 100% modulation. It is true that the antenna-current increase should be approximately 22.5% over no modulation when a sine wave is applied to the transmitter at 100% modulation value. Antenna-current increases for 100% program modulation, however, will be much less, due not only to the difference in peak factor, but also the sluggishness of the thermocouple r-f meter action. This slowness of action is due to the heating effect of the two dissimilar metals upon which the action of the meter depends.

Chapter 13

PROGRAMS *ARE* ENTERTAINMENT

DURING THE REGULAR broadcast day the transmitter operator keeps the circuits properly tuned, maintains correct power input to the final stage, logs meter readings each 30 minutes (which also aids in forestalling trouble), maintains frequency of operation within plus or minus 10 cycles, and maintains the program level at a point consistent with good engineering practice and the type of program in progress.

It is only natural that the program level being sent via wire line from the studio be the most concern from a strictly operational point of view to the transmitter operator. With competent studio personnel, the line amplifier gain adjustment may be set for 100% modulation on program peaks at the start of the day and left at that adjustment. Many times, however, the transmitter operator who does not appreciate musical and dramatic values will become piqued with the control operator when program level is very low. He should realize that broadcast stations are not strictly "communications," but intended to bring entertainment into the home with as much of the original intent as possible consistent with the state of the art. Certain types of programs, symphony concerts in particular, are meant for those listeners in the primary service area and not intended to override the noise level at some secondary service point. If the monitor speaker is turned up in volume consistent with that of the interested listener at home for these types of programs, the transmitter operator will be able to use good judgment as to whether the signal is entirely too low to be usable.

In relation to the study of program levels, it is of prime importance to understand the characteristics of indicating meters used at both ends of the transmission system. These meters differ in characteristics because of the different function which they are intended to perform. The standard vu meter used in most broadcast studios today is an rms-indicating full-wave rectifier device intended to give a close approximation visually of the sound waves emanating from the loudspeaker. We are concerned, however, with modulating voltages at the transmitter, and a semipeak indicating device is necessary and is required by the FCC. If peaks of the program signal content should be excessive and occur in rapid succession, danger of circuit component breakdowns would exist as well as severe adjacent channel interference. Therefore, since the peak factor of program waves is high as discussed earlier, the modulation meter is a "peak" indicating device. It is also necessary that a phase reverse switch be incorporated in the modulation meter circuit which switches the polarity of the input to the vacuum-tube voltmeter so that either the positive or negative side of the modulated envelope may be monitored separately. Thus it is obvious that we are confronted with two distinct types of level meters; namely, a *full-wave rms meter* at the studio and a *half-wave peak meter* at the transmitter. In addition to these meters, we usually have a limiting type amplifier (in most modern installations) which is used at the transmitter as a line amplifier. This has a meter which measures the amount of compression (full-wave peak meter) and output level in vu (full-wave rms meter).

Correlation of Meter Readings

The number of different types of indicating meters used should not confuse the operator as long as the proper interpretation is given to the readings. Fig. 13-1 is a representation of the indication of a pro-

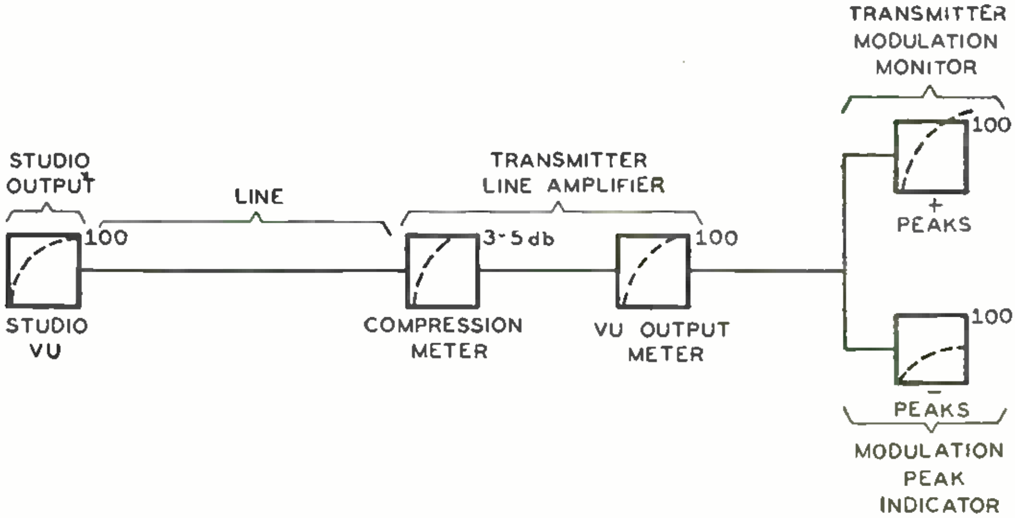


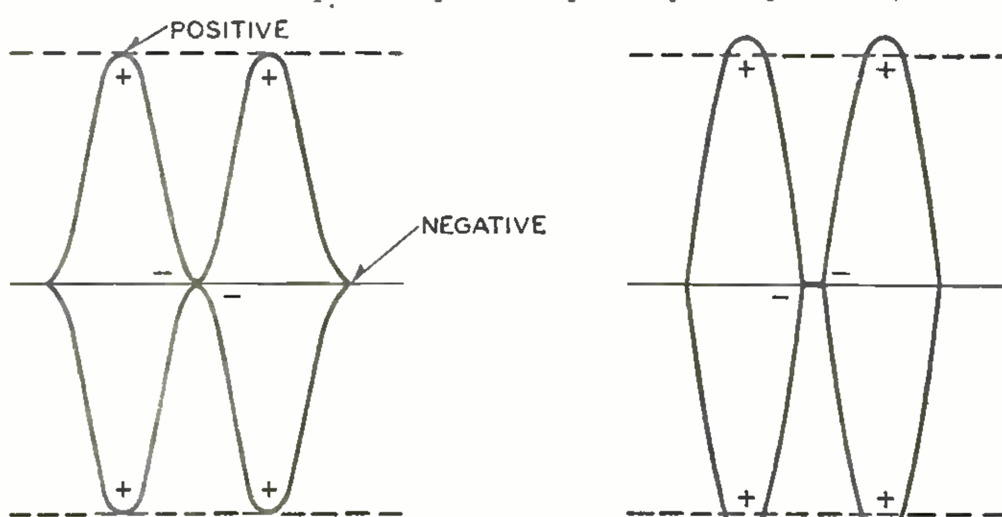
Fig. 13-1. A representation of the indications on the various meters of a program peak at any given instant.

gram peak *at a given instant* on the various meters involved. The studio vu meter has registered 100, the compression meter on the transmitter shows normal 5 db amount of limiting, the line amplifier output meter shows 100, and the modulation meter would show either 100% modulation on positive peaks, or, if set to monitor negative peaks, might show only 60% modulation. This, of course, could be just reversed with a change in polarity of the microphone output or any connection in between.

It is a well-known fact that speech waves are not equal in positive and negative peaks regardless of type of microphone used. This may be observed from the graph of the speech wave shown in Fig. 12-1. Two speakers working from opposite sides of a bidirectional microphone and "peaked" the same amount on the studio vu meter will *not* give equal indication at the modulation meter when set to indicate a certain peak (either positive or negative).

Assume, for example, that the modulation monitor switch is set to monitor the negative peaks, and the indication of one voice is close to 100%. The indication of the voice on the other side of the microphone (therefore oppositely poled at the microphone output transformer) may indicate only 40% or 50%, with the amplitude of the studio vu meter remaining the same. For this reason it is obvious why misunderstandings sometimes arise between studio and transmitter personnel regarding comparative level of two or more voices.

The question then arises as to what indication, if any, exists at the transmitter plant to show a true indication of comparative levels from the studio. It has been shown that the half-wave reading of the modulation meter, which depends upon the polarity of operation, is not a



Figs. 13-2. left. 13-3. A drawing (left) of an oscillogram showing a sine-wave carrier that is 100% modulated and one that is over-modulated is shown on the right.

true indication of *comparative* levels from the studios. The vu meter on the output of a limiting amplifier would not be a true indication since the output level is limited by the compression taking place in the amplifier for signals over a predetermined level. The compression meter, although a full-wave indicating device, is a peak reading instrument and, since the peak factor of program waves varies considerably, it is not an absolutely accurate indication of comparative levels. It is, however, the most reliable indication (within limits) existing at the transmitter, since it *is* full-wave rectified and is limited by only wire line characteristics. If two voices, for example, show about the same amount of compression, the comparative levels may be considered very nearly the same.

100% Modulation

Fig. 13-2 is a drawing of an oscillographic pattern of a 100% modulated (sine tone) carrier, showing what constitutes positive and negative modulation of the carrier. It may be seen that negative or "trough" modulation cannot attain more than 100% of the available range, whereas positive or "peak" modulation may go over 100%. When a carrier is thus modulated with a pure tone, the degree of modulation m is

$$m = \frac{\textit{average envelope amplitude} - \textit{minimum envelope amplitude}}{\textit{average envelope amplitude}}$$

and the peaks and troughs of the envelope will be equal. When the minimum envelope amplitude (negative peak modulation) is zero in the foregoing equation, the degree of modulation is 1.0 and the degree of modulation is complete, or 100% expressed in percentage modulation.

When the envelope variation is not sinusoidal, such as is true for program signals, the positive and negative peaks will not be equal as explained earlier, and the degree of modulation differs for peaks and troughs of modulation as follows:

$$\textit{Positive peak modulation} = \frac{E_{max} - E_{min}}{E_{av}} \times 100$$

$$\textit{Negative peak modulation} = \frac{E_{av} - E_{min}}{E_{av}} \times 100$$

Thus it is possible to understand the mathematical analysis of why the trough modulation cannot exceed 100%, since the minimum voltage cannot be less than zero. It may be seen, however, that the positive peak voltage may be more than twice the average (or carrier) voltage (E_{av}) in which case positive peak modulation will exceed 100% modulation. What important information does this hold for the transmitter operator?

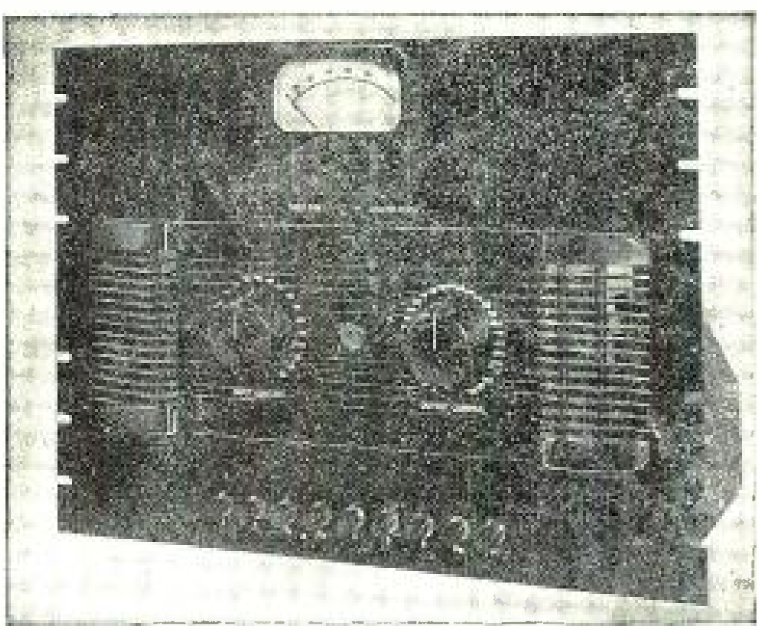
First, it should be clarified in the operator's mind that "overmodulation" *can* take place on the negative (trough) modulation as well as on the positive (peak) modulation. It is true that the *degree* of modulation can never exceed unity on the negative peaks, but *can* exceed unity on the positive peaks. Complete modulation (of a class C stage) however, requires that the peak value of the modulating voltage equal the d-c plate voltage of the modulated stage. Fig. 13-3 shows a drawing of an oscillographic pattern of a carrier wave with modulating voltage exceeding the d-c plate voltage causing overmodulation of the carrier. It is true that the positive modulation peaks exceed unity while the negative peaks are "cut off" by the excessive negative modulating voltage and cannot exceed unity. This excess energy, however, which allows the negative peak voltage to result in a voltage applied to the r-f amplifier plate circuit to become negative with respect to ground, causes a radiation of this excess energy in the form of spurious frequencies, resulting in "splatter" and adjacent channel interference.

This actually is "overmodulation" in its severest form, since positive peaks may extend beyond 100% modulation without amplitude distortion, whereas negative peak "overmodulation" will cause severe amplitude distortion. It will be remembered that the bandwidth occupied by the carrier and sidebands depends (for amplitude modulation) *not* upon the degree of modulation, but upon the highest frequency being transmitted. Amplitude distortion, however, resulting from negative peak overmodulation, generates a number of distortion frequencies at harmonics that may well extend high enough to spread the sidebands into channels adjacent to the assigned frequency of the transmitter in question.

This discussion has been presented in order to show the transmitter operator that the negative side of the modulation is the most important peak to monitor on the modulation meter, and to hold under 100% at all times. It is well to remember that the modulation meter of the vacuum-tube voltmeter type will *not* be able to indicate over 100% (negative) on the meter because the peaks cannot attain more than this value as shown before. This is the reason why a cathode-ray oscilloscope is invaluable at a broadcast transmitter to show negative peak "overmodulation," since the negative peak "clipping" shows up as white lines across the center of the modulated pattern. When the usual vacuum-tube voltmeter type of modulation indicator is used, the flasher should be set to flash at 90% or 95% modulation so that when observing negative peaks, the warning is given when the peaks go up *to* 100% modulating value.

Operation of Limiter Amplifiers

The limiting amplifier, also known as a compression amplifier (see panel view in Fig. 13-4) is a very important link in a broadcast installation. However, its effect may be small and detrimental, if the



RCA Photo

Fig. 13-4. Panel view of a limiting or compression amplifier for preventing overloading transmitter components and adjacent channel interference.

wrong operational interpretation is given to the main purpose for which it is designed and intended. This type of amplifier, as designed for use in a broadcast installation, is intended as a *peak limiting* device, the amount of gain reduction being a function of the program *peak* amplitude. In order to prevent material reduction in the dynamic range of the signal, the peak gain reduction is not intended to be more than 3 to 5 db. A broadcast limiting amplifier, therefore, should not be considered as a volume limiter, but as a peak limiter intended to prevent overloading of transmitter components and adjacent channel interference.

The original advertising claims of manufacturers offering this type of equipment proved misleading from an *operational* point of view. It is true that doubling the output power of a transmitter raises the signal intensity 3 db. It is also true that the limiter amplifier also raises the signal level about 3 db on *program peaks*. To those familiar with watching volume indicators on program circuits, however, this 3-db increase on speech or music is of small consequence. As far as the transmitter operator is concerned, he should think of this amplifier as a protective device to limit peaks caused by wire line transmission and those program peaks that escape the action of the control-room operator.[1]

That the primary purpose of a limiting amplifier may be defeated by erroneous operation is a very important fact for the broadcast operator to know. Seriously detrimental effects will result if this amplifier is operated as an actual "volume compression" device to attempt to prove a coverage area greater than a given power and transmitter location warrants. The "attack" time of peak limiting (about 0.001 second) is determined by a resistor-capacitor charging circuit with the inherent characteristics of a low pass filter. At high frequencies, and where the duration of the peak is short compared to this operating time, a portion of the peak energy will escape limiting action. If the average signal level is so high that a great amount of compression takes place at all times, a larger amount of adjacent-channel interference will result, thus defeating one of the main purposes of the amplifier.

This has been quite noticeable in practice when the program content consists of music from dance orchestras of brass instruments where high peak powers at high frequencies are very prevalent. A limiting amplifier operated properly for broadcast service will show about 3 to 5 db of intermittent gain reduction as indicated by the peak reading meter used to show the amount of program peak compression. The operator must realize that for certain types of programs such as symphonies, liturgical music, and operas, the average audio signal may be very low over a period of time even with limiting amplifiers in use. Dynamic range is just as important to high-fidelity transmission of these types of programs as is the frequency range.

Another consideration is the recovery time value, or time required to restore the gain to normal after a peak has momentarily reduced the gain. Optimum recovery time may well be different for different

[1] See Appendix for important adjustment of the 96-AX limiting amplifier.

types of program material. Piano music, for example, sounds unnatural when recovery time is too short, because the effect is similar to inadequate damping of the strings after they are struck or to holding the sustaining pedal too long on the loud notes. The longer the recovery time is made, however, reduced gain will be in effect a larger proportion of the total time, and will result in unnatural transmission of certain passages in specific musical compositions. When operated properly in accordance with good operating practice, and not subjected to more than the specified amount of peak load, very satisfactory results may be obtained.[2]

When thinking of a compression amplifier as a means of increasing the service area of a transmitter, it is well to keep in mind the known facts concerning the psychological differences that exist in listening habits for various types of programs. A lower relative signal level is tolerable for dance music, news broadcasts, etc., where the average audio level is high over a period of time. In this case where listeners well outside the "primary service area" of the station may be numerous, the maximum amount of peak limiting may be used to help raise the signal-to-noise ratio at the receiving point. It is realized, however, that symphony broadcasts, choral music, certain liturgical music, opera, etc., where the average audio signal may be very low over a period of time, will appeal only to those listeners who are very adequately served with strong carrier signals. In the interests of preserving the original dramatic effects of this type of program, *it simply is not technically feasible for a broadcaster to attempt to set a fixed value of coverage area for all types of program material.* Similarly, the operator responsible for the transmission of programs should not attempt to operate all equipment in the same manner regardless of type of programs being transmitted.

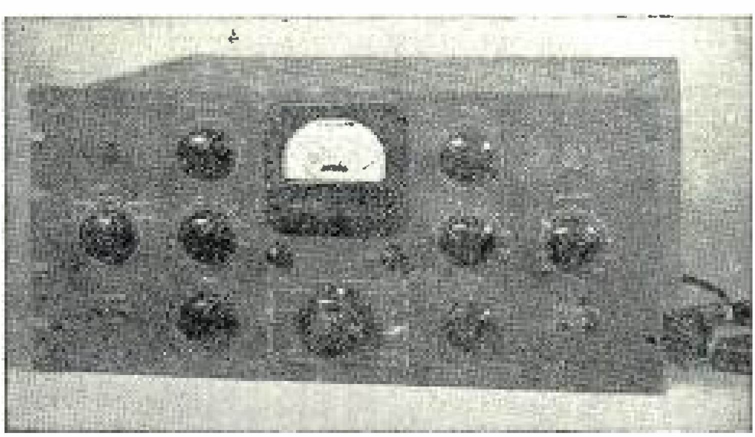
[2] W. L. Black and N. C. Norman, "Program-Operated Level-Governing Amplifier," IRE *Proc.*, Nov. 1941.

Chapter 14

MEASURING NOISE AND DISTORTION

THE IMPORTANT CHARACTERISTICS of any modern broadcast installation are adequate frequency range to convey as much of the original sound as possible, low noise and distortion levels necessary for required dynamic range, and dependability of performance. One of the most important pieces of auxiliary equipment about a transmitting plant is the instrument for determining noise and/or distortion over the usable frequency range to facilitate proper adjustment of the over-all installation. Several manufacturers are supplying such equipment for broadcast frequencies, and most stations are equipped with means of checking noise and distortion. Definite instructions accompany all such equipment, but a typical description of procedure for using one type of noise and distortion test equipment is given here in outline form as a matter of general interest. This outline conveys the general principles of all noise and distortion measuring equipment.

Fig. 14-1 is an illustration of the RCA 69-C Distortion and Noise meter, which may be used to measure distortion in transmitters or audio equipment at any frequency from 50 to 7500 cycles, providing



RCA Photo

Fig. 14-1. Meter for measuring distortion in transmitters or a-f amplifiers from 0.3% to 100% and noise levels down to —85 db below 12.5 milliwatts.

measurements of rms total distortion from 0.3% to 100% and noise levels down to minus 85 db below 12.5 milliwatts. This instrument consists essentially of a diode detector which is used when taking measurements on a transmitter to demodulate the modulated r-f signal,

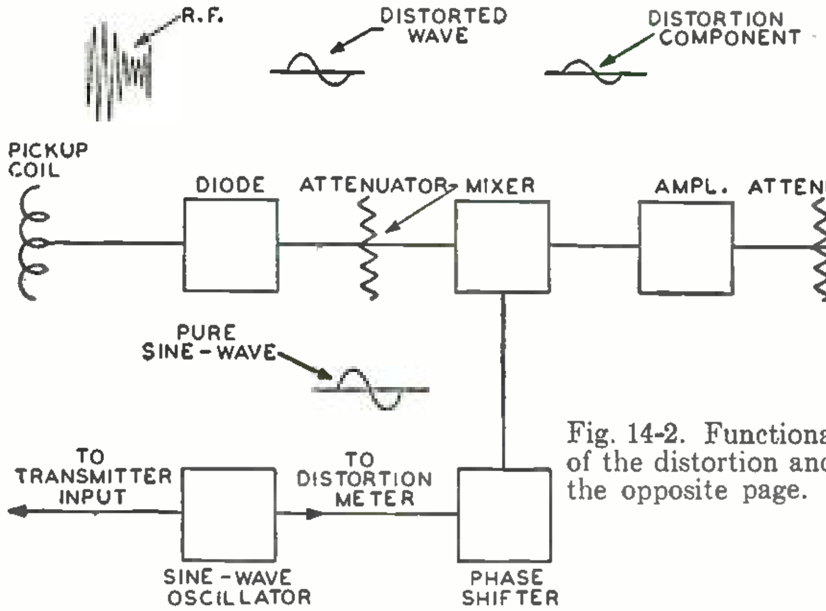


Fig. 14-2. Functional block diagram of the distortion and noise meter on the opposite page.

an attenuator to adjust the audio output of this detector, a phase-shifting network, a mixer stage to combine the output of the attenuator with that of the phase shifter, an amplifier, a range attenuator to adjust amplifier gain, and the meter which measures the amplifier output.[1] A functional diagram is shown in Fig. 14-2.

In operation, a sine wave from a stable oscillator is applied both to the transmitter and the phase shifter of the RCA 69-C meter. The phase-shifting network is adjusted until the signal is exactly in phase with that derived from the output of the transmitter. The output signal from the transmitter is adjusted in amplitude by the attenuator so that its fundamental-frequency component is exactly equal to the output of the phase shifter. In other words, the amplitude and phase controls are adjusted until a minimum meter reading is obtained. Each of these two signals is impressed on the grid of one of two mixer tubes, whose plates are connected in push-pull by means of a transformer. The difference voltage of the two input signals appears across the secondary of this transformer and is at minimum value when the distorted and undistorted signals are adjusted in phase and amplitude to have minimum difference. With this adjustment, the

[1] For schematic and other data, see Appendix.

fundamental-frequency component of the distorted signal is canceled out by the sine-wave signal, the difference voltage containing the distortion components. This difference voltage is amplified and the meter reads the total rms distortion directly.

Noise and distortion measurements should be run on broadcast transmitters at least every six months, as well as a complete frequency run to determine frequency response of the equipment. For the guidance of the transmitter operator, the following excerpts from the "FCC Standards of Good Engineering Practice" that directly affect his duties, are presented.

Excerpts From Standards

Section 3.46 requires that the transmitter proper and associated transmitting equipment of each broadcast station shall be designed, constructed, and operated in accordance with the "Standards of Good Engineering Practice" in addition to the specific requirements of the "Rules and Regulations of the Commission."

The specifications deemed necessary to meet the requirements of the "Rules and Regulations" and "Good Engineering Practice" with respect to design, construction, and operation of standard broadcast stations are set forth in the following text. These specifications will be changed from time to time as the state of the art and the need arises for modified or additional specifications.

A. Design. The general design of standard broadcast transmitting equipment [main studio microphone (including telephone lines, if used, as to performance only) to antenna output] shall be in accordance with the following specifications. For the points not specifically covered, the principles set out shall be followed.

The equipment shall be so designed that:

(1) The maximum rated carrier power (determined by section 3.42) is in accordance with the requirements of section 3.41.

(2) The equipment is capable of satisfactory operation at the authorized operating power or the proposed operating power with modulation of at least 85 to 95 per cent with no more distortion than given in (3).

(3) The total audio-frequency distortion from microphone terminals, including microphone amplifier, to antenna output does not exceed 5% harmonics (voltage measurements of arithmetical sum or r.s.s.) when modulated from 0 to 84%, and not over 7.5% harmonics (voltage measurements of arithmetical sum or r.s.s.) when modulating

85% to 95%. (Distortion shall be measured with modulating frequencies of 50, 100, 400, 1000, 5000, and 7500 cycles up to the tenth harmonic or 16,000 cycles, or any intermediate frequency that readings on these frequencies indicate is desirable.)

(4) The audio-frequency transmitting characteristics of the equipment from the microphone terminals (including microphone amplifier unless microphone frequency correction is included, in which event proper allowance shall be made accordingly) to the antenna output does not depart more than 2 db from that at 1000 cycles between 100 and 5000 cycles.

(5) The carrier shift (current) at any percentage of modulation does not exceed 5%.

(6) The carrier hum and extraneous noise (exclusive of microphone and studio noises) level (unweighted r.s.s.) is at least 50 db below 100% modulation for the frequency band of 150 to 5000 cycles and at least 40 db down outside this range.

B. Operation. In addition to the specific requirements of the rules governing standard broadcast stations, the following operating requirements shall be observed:

(1) The maximum percentage of modulation shall be maintained at as high a level as practicable without causing undue audio-frequency harmonics, which shall not be in excess of 10% when operating with 85% modulation.

(2) Spurious emissions, including radio-frequency harmonics and audio-frequency harmonics, shall be maintained at as low a level as practicable at all times in accordance with good engineering practice.

(3) In the event interference is caused to other stations by modulating frequencies in excess of 7500 cycles or spurious emissions, including radio-frequency harmonics and audio-frequency harmonics outside the band plus or minus 7500 cycles of the authorized carrier frequency, the licensee shall install equipment or make adjustments which limit the emissions to within this band or to such an extent above 7500 cycles as to reduce the interference to where it is no longer objectionable.

(4) The operating power shall be maintained within the limits of 5% above and 10% below the authorized operating power and shall be maintained as near as practicable to the authorized operating power.

(5) Licensees of broadcast stations employing directional antenna systems shall maintain the ratio of the currents in the elements of the

array within 5% of that specified by the terms of the license or other instrument of authorization.

(6) In case of excessive shift in operating frequency during warm-up periods, the crystal oscillator shall be operated continuously. The automatic-temperature-control circuits should be operated continuously under all circumstances.

Part 5

WE'RE OFF THE AIR

Chapter 15

EMERGENCY SHUTDOWNS

THIS IS the situation that invariably causes a state of panic in the newcomer to a transmitter operating job. In nearly all instances he is alone, with the responsibility of correcting the trouble as quickly as possible to avoid loss of revenue by his employer. The highest efficiency in correcting trouble will come with more experience at the particular installation. The operator, however, who can visualize general circuit theory in relation to the particular circuits with which he is concerned will find a logical and natural sequence of looking for the fault. The *main* requirement quite naturally is to become thoroughly acquainted with the circuits used. He should be able to draw from memory a good general *functional* picture of all circuits, and be able to draw a block diagram of the sequence of operation of starting relays and protective relays in the power-control circuits. It is obvious that confidence and peace of mind can be achieved only by a complete familiarity with all circuits and their relation to the over-all performance of the transmitter.

It is, of course, impossible to set down a definite method of locating and clearing specific troubles of any kind or description. We hope, however, to be able to set forth a clear concise approach to procedures in general; that is, a logical and straightforward means of meeting emergencies.

There is one piece of equipment at the transmitter installation that should be the central focusing point for the operator's first attention when trouble occurs. This is the modulation meter which has an r-f input indication meter that reads a definite place on the scale for normal operation, and, of course, the percentage modulation indicator. The purpose of this will be evident in the following discussions.

At the first interruption of the program, or the occurrence of noise or distortion in the monitoring loudspeaker, this modulation monitor should be observed. Let us assume that the r-f input meter is at normal scale which assures us that the trouble is not in the r-f section because any trouble there would cause some deviation in the r-f input to the meter.

The following is a procedure to follow when the program suddenly stops from the loudspeaker:

1. *R-f input meter shows normal, modulation meter shows modulation taking place.* Trouble obviously in monitoring line or amplifier and we are *not* off the air.
2. *R-f input normal, no modulation as shown on meter.*
Trouble either in audio section of transmitter, line amplifier, program line from studio to transmitter, or at studio.
Call studio control to ascertain condition at that point. If everything there is normal, check line by patching line into monitor amplifier or spare amplifier to see if program is coming into the transmitter from line. If not, notify control to feed program on spare line and call local test board of Bell Telephone Co. If coming in satisfactorily from line, use spare line amplifier to feed transmitter. If the regular line amplifier is working normally, then the trouble obviously lies in the audio section of the transmitter itself. Usually any trouble here will be indicated by abnormal plate-current meter readings, and, of course, tube trouble is the most common source of program interruption.

The same procedure should be used where noise or distortion occurs, first checking with studio, then line, line amplifier, and audio section of transmitter. If all speech input tube currents are zero, then the trouble is in the associated power supply. Most likely trouble again is due to a tube, and it should be changed upon indication of abnormal plate current. Next in line comes bleeder resistors, resistor taps from bleeder supply, and line-to-plate circuits of tubes. Power-supply component parts usually show a visual indication of damage, such as a smoking part, unless opened up.

If, at the first indication of trouble, a glance at the modulation monitor position shows zero or low r-f input, then the trouble lies in the r-f stages of the transmitter. The operator must accordingly proceed to check for the trouble in the r-f section by observing all r-f circuit meter indications. Observation of plate and grid current meters aid in quickly determining the faulty stage.

When the transmitter is shut down by relay operation in the control circuits, the cause of the failure is quickly traced if the operator is familiar with relay sequence and functions. Control circuits are divided into two functional purposes: (1) those which control circuits to the primaries of power supplies, and (2) those of protective functions. Pilot lights are often associated with the various relays to show when open or closed. As stated before, the sequence of operation should be committed to memory. The filament power supply, for example, will not operate until the cooling motor contactors have functioned to supply the cooling medium (water or air) to the tubes. After the filament contactor has applied filament voltage, the plate-voltage contactor will not operate until the time delay relay has functioned, etc.

Rectifier tubes of the mercury-vapor type nearly always arc-back several times before expiring. When arc-back indicators are used, the faulty tube may be quickly observed and changed immediately. Other troubles in high-voltage power supplies nearly always show signs of physical deterioration as stated before.

Short circuits which cause a quick tripping of overload relays are always the most difficult troubles to locate. In some difficult troubles of this kind, overload relays have been strapped out of the circuits, and limiting resistors put in the lower current fuse box to limit the amount of current flowing. The circuits were then visually observed for arc-overs with doors open and interlock switches short-circuited. This is a dangerous procedure, however, and should be left to the more experienced operators. More than one man should carry out any unusual procedure of this kind.

This all may be summarized into the most important factor. *Be familiar with the transmitter*, and know what indications would be for the most common sources of trouble such as tubes and power supplies for the various circuits.

Chapter 16

WHY PREVENTIVE MAINTENANCE

THE PRIMARY PURPOSE of any preventive maintenance schedule, of course, is to reduce as much as possible the likelihood of failure during the broadcast day of any component part of the broadcasting installation. Regular maintenance schedules are in force at most broadcast stations, and do much to increase their useful life and anticipate and prevent many tube and parts failures that would occur if neglected.

Preventive maintenance of any sort of equipment may be defined as a systematic series of operations performed periodically on the equipment in order to prevent breakdowns. This type of maintenance may be divided into two phases: work performed while the equipment is functioning and work performed during the normal shutdown periods. Here we are concerned only with the shutdown period preventive maintenance.

The importance of preventive maintenance cannot be overestimated. The owners of a broadcast station depend upon its being on the air every second of its scheduled periods of transmission. It is of the utmost importance that the personnel of radio stations properly maintain their equipment so that lapses in the transmission will be kept to a minimum.

Cleanliness of equipment is of utmost importance since collection of dust and dirt has been known to cause a number of troubles. This is particularly true in the higher power stages of transmitters, since accumulation of foreign matter over a period of time reduces the voltage insulation to a point where leakage currents and arc-overs are common. High-voltage contacts have an extreme tendency to collect dirt (this is the principle used in electronic smoke eliminators), and the higher relative humidity existing in summertime or southern locations tends to aggravate this characteristic. A dusting and clean-up procedure, then, is a desirable nightly procedure at a transmitter plant. A source of dry air under pressure is a common means of blowing out dirt, dead insects, and the like from inaccessible corners and variable tuning capacitors. Insulators, safety gaps, etc. should be polished with a dry cloth or carbon tetrachloride used to loosen excessive dirt and grime.

Proposed Transmitter Maintenance Schedule

In order that preventive maintenance be effective, it is essential that it be performed at regular intervals; that is, certain portions of the equipment must be inspected for certain things every day while other parts of the equipment need only be inspected weekly or monthly in addition, of course, to those things which are inspected daily. Below will be found a comprehensive maintenance schedule[1] which may be considered as a guide to anyone desiring to set up such a means of preventing breakdowns. Naturally, items may be included in this schedule which may be felt to be unnecessary at some particular transmitter, but it has been compiled with the thought that every precaution should be taken.

Later on in this chapter will be found the actual preventive maintenance schedule which is followed at Station WIRE.

TRANSMITTER MAINTENANCE

A. DAILY

1. Hourly read all meters and check power tube filament voltages.
2. Check air-cooled anode temperatures. Check water temperature of water-cooled tubes.
3. Check for correct cabinet temperature of air around high-voltage rectifiers.
4. After shutdown make a general inspection for overheated components, such as capacitors, inductors, transformers, relays, and blowers.
5. Investigate any peculiarities of meter readings.
6. In the event of overloads, examine safety gaps and transmitter components for arc pits, etc. Clean and repolish surfaces where arcs have occurred. Reset gaps if necessary. Investigate cause of outages.
7. In the event of lightning or heavy static discharges, inspect the transmission line, terminating equipment, and antenna including gaps. Polish pitted surfaces.
8. If gas filled co-ax is used, check pressure.

[1] By courtesy of RCA Mfg. Co.

B. WEEKLY (In addition to above)

1. Immediately after shutdown, check antenna terminating components for signs of overheating.
2. Clean antenna tuning apparatus. Check for arc pits, etc. Clean and polish gaps and adjust if necessary.
3. Test antenna monitor rectifier tubes.
4. Calibrate remote antenna meters against meters in the antenna.
5. Clean transmitter with vacuum.
6. Clean component parts of transmitter.
   a. Brush terminal boards,
   b. Clean insulators with carbon tet,
   c. Clean power tubes and high voltage rectifiers with tissue and alcohol (or distilled water).
7. Check filament voltages and d-c voltages at the tube socket of all tubes which are not completely metered by panel meters.
8. Check air flow interlocks for proper operation. Check all door interlocks for proper operation.
9. Check operation of grounding switches. Examine mechanical operation and electrical contacts.
10. Inspect blowers for loose impellers, free rotation, and sufficient oil.
11. Inspect relays for proper mechanical and electrical operation. If necessary, clean and adjust components.
12. Inspect air filters; clean if excessive dirt has accumulated.
13. Check all sphere and needle gaps. Clean any pits or dirt. Check gap spacings.
14. Check filter bank surge resistors with ohmmeter.
15. Check any power tube series resistors with ohmmeter.
16. Check power change switches if used; check for no serious arcing during day-night antenna change-over if used.
17. Make general performance check-up. Distortion, noise, and frequency response. Observe modulated wave form on CRO.
18. Check neutralization by cutting crystal oscillator and observing grid currents. Observe overmodulation waveform envelope on CRO.
19. Check proper operating voltage for pure tungsten filament tubes. Operate at lowest voltage permissible as indicated by:
    a. AM transmitters—distortion and carrier shift checks.
    b. FM transmitters—decrease filament voltage until output begins to drop.

c. Operate filaments approximately 1% above filament voltage determined in a or b.

20. If water cooling is employed check entire system for any signs of leakage and for electrical leakage.
21. Check pressure of any gas-filled capacitors.

C. MONTHLY (In addition to above)

1. Make detailed inspection of all transmitter components with whatever tests of parts that may seem advisable.
2. Clean and inspect all vacuum and rectifier tube socket contacts, and the tube pins.
3. Clean air filter or replace. Brush dust from blower impellers, canvas boots, etc.
4. Clean and adjust all relay contacts. Clean pole faces on contactors. Replace badly worn contacts.
5. Oil blower motors (carefully).
6. Operate all spare vacuum tubes for a minimum of two hours under normal operating conditions. Clean up any gassy tubes.
7. Operate all spare mercury vapor rectifiers normally, after first applying filament only for a minimum of 30 minutes. Store tubes upright.
8. Inspect all variable inductor contacts for tension, signs of overheating, and dirt. Clean and adjust as required. Carbon tet or crocus cloth may be used for cleaning. Do not use emery cloth.
9. Check for proper operation of time delays, notching relays and any automatic control systems.
10. Clean audio equipment (console, etc.) attenuator and low level switching contacts with cleaner; wipe off excess.
11. Check tubes in station monitor equipment, such as frequency monitor, modulation monitor, etc.
12. Clean switches in monitoring equipment with cleaner.

D. QUARTERLY (In addition to above)

1. Lubricate tuning motors and inspect for ease of rotation.
2. Check all indicating meters (a-c, d-c, r-f). Check a-c filament voltmeters with an accurate dynameter type of meter.
3. Check *all* connections and terminals for tightness.
4. Inspect any flexible cables to door connections.
5. Inspect and lubricate if necessary any flexible drive cables.
6. Inspect, clean, and service (if necessary), all switches. Volt-

meter selector switches, push button switches, control switches, etc.

7. Clean transmission line insulators and take up slack if open wire lines are used.
8. Check oil circuit breakers, if used, for sufficient oil and loose or defective parts.

E. SEMIANNUALLY (In addition to above)

1. Test transformer oil for breakdown and filter it if necessary (power company).
2. Check protective overload relays or circuit breakers for correct operation.
   - a. A-c overload relays may be checked by shorting the high-voltage transformer secondary.
   - b. D-c overload relays may be checked by shorting the d.c. through the relay in the circuit protected by the relay.

MAINTENANCE SUGGESTIONS

A. CONTACTORS—GENERAL

1. Inspect all parts at regular intervals.
2. Parts should be kept free of dirt, grease, and gum.
3. Replace contact tips as needed (keep spares on hand).
4. Keep all contacts and interlocks clean and free from burrs and pits.
5. Main copper contacts should not be lubricated. Darkened tips due to overheating, or copper beads should be dressed with a fine file. (Do not use emery cloth.)

B. CONTACTORS—HUM

1. Clean off rust, dirt, or grease from pole piece and armature and apply a small quantity of light machine oil to prevent rusting.
2. Check pole shader and its circuit. Armature contact surfaces above and below shader should be approximately equal.
3. Armature to pole piece contact should be made over a large area; gaps should not be over 1/1000 to 2/1000 inch. If the contact area is small or the gap too wide, the pole face may be ground or filed down to a FLAT surface.

C. CONTACTS—SILVER

1. If not burned or pitted they may be cleaned with a contact burnishing tool.
2. If burned and pitted, dress with a small fine file and polish with crocus cloth.

Maintenance of Water-Cooling Systems

As has been stated before, it is not the purpose of this section to duplicate otherwise available data on the engineering aspects of transmitting equipment. However, since cooling systems of transmitters of more than 1-kw rating are so highly important to the problem of keeping the station on the air, some factors of operating and maintaining these cooling systems that have not been emphasized before will be presented here for the operator's convenience.

Fundamentally, the power rating of a tube in free air is determined by three characteristics, namely:

1. Plate voltage that may be safely applied (dependent on physical parameters).
2. Electron emission of filament.
3. Amount of heat that can be dissipated at anode without causing overheating (dependent on physical and electrical parameters).

Thus it becomes apparent that insofar as the operator is concerned, the third characteristic is the only variable in the problem of heat dissipation, since electrical parameters such as operating angle in electrical degrees, bias voltage, etc. are more or less under the direct supervision of the operator.

In water-cooled systems, the temperature of the water at the outlet of the tube jacket should never exceed 70° C. (158° F.) as indicated by the water thermometer at that point. The rate of flow should be approximately 15 gallons per minute; 20 gallons per minute is more beneficial in retarding accumulation of foreign matter in the jacket and the prevention of steam bubbles along the anode surface. The effect of increasing the flow of water is to increase the turbulency of flow. This increased turbulency breaks down the layer of steam present at the anode wall and increases the heat exchange between the wall and the water. The turbulency of the flow may be increased by mechanical means, such as baffles.

Extraordinary precautions must be taken in the installation of the tube in the water jacket. The movable metal parts of the jacket should be coated with a light film of oil to help prevent corrosion. The tube should then be placed gently in the jacket, and after it is correctly seated the retaining studs or jacket clamping device is fastened firmly into place to force the flange of the plate into solid contact with the watertight gasket. The electrical connections may then be made. Care should be taken that the wires are not near or do not touch the glass bulb. Should this precaution be neglected, puncture of the glass from corona discharge is likely to occur. Particular care should also be observed in making the connection between hose and jacket tight and clean. Because of electrolysis, trouble is likely to develop at this point, and close inspection every two or three weeks is advisable.

A reasonably rigid maintenance schedule should be observed on the entire system to forestall trouble from water leakage, scale formation, or the formation of steam bubbles with resultant transmitter shutdown and loss of time on the air. Leaks, of course, may be temporarily sealed to a certain extent by using friction tape until permanent repairs can be made after sign-off. In some instances, it is possible to cover the radiator used to cool the water with a blanket until the inlet temperature of the water rises to around 104° F., resulting in a slight expansion of the parts which will aid in sealing a minor leak.

Scale formation, if and when it occurs, will prevent adequate transfer of heat from anode to water. If it becomes necessary to remove the tube for this or any other reason, the tube should be lifted carefully from the jacket after the clamping device has been released. Sticking of the tube often occurs, and in this case a gentle twisting back and forth while lifting will free the tube. Immersion of the plate in a 10% solution of hydrochloric acid is usually recommended to dissolve scale formation. The anode should then be rinsed thoroughly in distilled water.

The formation of steam bubbles may be checked periodically by using a good insulating rod at least six feet long. This should be moved along the jacket while aural observations are made. Precautions should be taken to assure the operator's safety, including grounding the testing tube between water jacket and the observer by a "hot stick" or similar arrangement.

A convenient way for the operator to keep an approximate check on the heat dissipation of the tube is by use of the formula:

$$P(KW) = \frac{n\,(t_o - t_i)}{4}$$

where:

t_i = known initial temperature of water in degrees C
t_o = temperature of water at jacket outlet in degrees C
n = rate of flow in gallons per minute.

It should be remembered here that the filament heat is also being dissipated into the water. It is recommended that the operator read the manufacturer's instructions that come packed with transmitting tubes. Some of the foregoing information is from RCA tube instruction sheets.

Forced-Air Systems

Although the problems of deteriorating hose, leaky hose connections, electrolysis, and troublesome flow-interlocks have been largely overcome by porcelain reels, reliable flow-interlocks and completely nonferrous circulating systems (all-copper tank and pipes), the familiar problems have remained of scale formation, gradual water evaporation, and relatively large time consumption in changing tubes.

In recent years, the elimination of the water-cooling system has been accomplished for transmitters up to and including 50-kw rating by the development of forced-air cooling systems. Control circuits for this system are greatly simplified, consisting as they do of an air-interlock damper on top of the blower motor, which prevents application of filament and plate voltages until normal air-flow pressure is present, and a blower motor "keep-alive" relay, which is a time-delay relay keeping blower motors functioning 4 to 7 minutes after filament voltage is removed.

Maintenance of forced-air systems is simpler than that of water systems but is just as important for trouble-free operation.

The canvas air ducts should be cleaned about once a month by removing them, turning them inside out, and using a vacuum cleaner to remove accumulated dirt. While these ducts are removed, a cloth may be used to slide between the fins of the tube, especially in against the tube anode, to remove dust. Care should be taken not to damage the mercury air-flow switches which are mounted on the blower housing. These switches prevent the application of filament and plate voltages until proper air flow is present. Both sides of the air-flow vanes (half-circle disks used to operate the mercury switch) should be wiped clean with a cloth or chamois and a small wire brush may be used to clean the corners of the fan blades. A vacuum cleaner then should be used to pick up any dust from inside the bottom of the blower frames.

After this cleaning procedure has been carried out, the blowers should be started to check the air-flow vanes for proper operation of the mercury switches, canvas ducts replaced, and over-all operation checked.

STATION WIRE PREVENTIVE MAINTENANCE SCHEDULE

The following preventive maintenance schedule has been in use at Station WIRE and as may be seen from designations, it is planned to have this work done on each Thursday night after the transmitter goes off the air. This arrangement is different from the general schedule presented earlier in this chapter inasmuch as some of the maintenance operations are performed weekly, others monthly, and the last group is performed five or six times per year.

First Thursday Night of Month Maintenance Schedule

Before turning main transmitter off, after conclusion of program from studio, read both North and South Tower Antenna Current meters. Check and adjust Remote-Reading Antenna meters, on the operating console, to read with their respective Tower meters. Turn main transmitter off in accordance with the usual sign-off procedure.

Shift antenna change-over switch to the Auxiliary Transmitter side. Turn on Auxiliary Transmitter for one-half hour check. Make regular transmitter log on this half-hour operation. Also, enter the readings of both the Antenna Current and Remote-Reading Antenna meters on this log sheet.

In addition to the daily sign-off procedure, carefully remove the two oscillator tubes and wipe them free of dust.

Clean both sides of plate glass partitions in front of the three large tubes. Use damp cloth on this and dry with paper hand towel.

Open all glass meter partition doors at top of transmitter and clean glass on both sides. Clean all glass meter faces including those on the power panel and Audio racks.

After Auxiliary Transmitter has been tested, turned off and log completed, BE SURE TO RETURN ANTENNA CHANGE-OVER SWITCH TO THE 5-D OPERATING SIDE.

Vacuum—clean the top of transmitter cabinets.

Wipe off all insulators on top of transmitter and insulators holding copper bus bar to rear wall, and all insulators on top of phasing cabinet (to transmission line), and all insulators on modulation transformer and reactor.

Wipe off all insulators and all components on the filter rack (filter condensers, reactors, resistors, relays, etc.).

Remove all rectifier tubes (remember to keep them upright in case of mercury-vapor rectifiers) from their sockets. Remove the shields and clean the sockets and other components under shields.

Open all front interlock doors. Use vacuum to clean all reachable space from the front, behind center panels, tube shelves, and floor plates.

Wipe off the four high-voltage insulators between modulator blower motors and the insulator above each of the high-voltage rectifiers. Also the insulators above the first and second audio stage tubes. Wipe off insulators on condenser above power-amplifier blower motor. Also the rectifier and oscillator feed-thru insulators in bottom of Exciter Unit.

Clean all components in modulator section ABOVE the final-tube holders. Inspect and tighten all connections in this half section.

Open rear doors on modulation and final stage. Wipe off floor of both from the rear. Wipe off all three blower frames. BE VERY CAREFUL OF ALL INSULATORS, ESPECIALLY MICALEX.

Take and record reading of "Filament Elapsed Hours Clock."

REPORTS: Make Transmitter Operating Room Report, as shown in Fig. 16-1, that this schedule was completed or any deviations from it. Also any other observations made.

TRANSMITTER OPERATING ROOM REPORT

DATE 7-15-1947 TIME 5:34 pm AM/PM

PROGRAM Melody Billboard (Musical ET)

ANNOUNCER Fisher

CONTROL OPERATOR [illegible] ORIGINATED STU C (BT)

TRANSMITTER OPERATOR [illegible]

REMARKS:

Carrier off thirty seconds due electrical storm.

Pigtail lead on directional antenna relay in phasing unit burned open. Replaced with temporary clip jumper.

BY [illegible]

(FILE IN DUPLICATE WITH CHIEF ENGINEER)

Fig. 16-1. An example of a transmitter operating-room report as used by the author at Station WIRE.

FINAL CHECK: Turn on transmitter in usual manner, first on low power of 1000 watts. If everything is normal then check the 5000-watt operation.

Second Thursday Night of Month Maintenance Schedule

Remove canvas air ducts beneath modulator and final tubes and place paper or cloth cover over blower openings. Carefully clean between fins of all three large tubes by sliding cloth between fins especially in against tube anodes.

Clean all components in lower half of modulator section. Check all components in this section including terminal blocks.

Remove temporary cover over blower openings. Wipe off both sides of air flow vanes. Check for free movement.

Brush corners of fan blades with small brush, then vacuum.

Some dust usually remains in bottom of blowers and should be removed by running each blower and using a deflector over blower opening on top to direct air away from tube bases. After all three are cleaned, and with blowers running, check to see that the air-flow vanes are operating mercury switches properly.

Replace canvas air ducts, and double-check for proper cond.

Run regular Auxiliary Transmitter test.

REPORTS: Make Transmitter Room Report that this schedule was completed or any deviations from it. Also report if conditions of air filters on back doors necessitates replacement.

FINAL CHECK: Check for low power and high power operation in usual manner.

Third Thursday Night Maintenance Schedule

Regular Auxiliary Transmitter check.

Clean relay contacts in phasing unit.

Inspect and clean lightning gaps on transmission line above phasing unit.

Tighten and clean all connection and chassis of tuning assemblies in tower houses. Clean relay contacts.

Check relay operation for Directional and Non-Directional operation by turning transmitter on as outlined for previous maintenance schedules.

Fourth Thursday Night Maintenance Schedule

Regular Auxiliary Transmitter check.

Clean input and output attenuators on 96-A line amplifier, also monitor attenuator. (Use Lubriplate and clean cloth.)

Vacuum jack strips on speech input panel.

Inspect for tightness connections on relays in power-control panel. Clean the above relay contacts.

Wipe off filament rheostats on power control panel.

Wipe off all accessible places on power control panel.

Clean "modulator bias" relay contacts.

Clean the contacts of the two overload relays and time-delay relay in exciter unit.

Clean and inspect all components in exciter unit not covered in previous schedules.

Vacuum inside of power-control console, tighten all connections.

Regular transmitter check for normal operation.

Fifth Thursday Night Maintenance Schedule (where this occurs)

Regular Auxiliary Transmitter check.

Check all tubes (with tube checker) of 96-A line amplifier and associated power supply, modulation monitor, frequency monitor, program monitor, and speech input tubes.

Check 6K7 balance in 96-A line amplifier.

Check spare line amplifier for proper operation.

Check lubrication of all motors including toilet and shower water pumps and exhaust fans.

Take inventory of new transmitter log sheets, transmitter-room report sheets, spare tubes, spare fuses, indicator lamps, and illuminating lamps for building and towers.

Chapter 17

PREVENTIVE MAINTENANCE INSTRUCTIONS

IN THE PRECEDING chapter some general facts about preventive maintenance were presented together with schedules showing when the different operations should be performed. Inasmuch as some of these operations deal with apparatus that can easily be damaged unless proper care is exercised, certain procedures should be followed so that no damage does result from the periodical inspections and so that if repairs to the apparatus are necessary, they can be effected properly. It should be borne in mind that the data in the following pages are general for the most part and it may be that some manufacturers recommend specific procedures for their products, which, of course, should be followed.

The reasons why preventive maintenance operations are followed seem obvious with no further comment. It might be well, however, for the men who are responsible for this maintenance work to keep in mind that the procedures discussed in the following pages have been designed to

1. Combat the detrimental effects of dirt, dust, moisture, water, and the ravages of weather on the equipment.
2. Keep the equipment in condition to insure uninterrupted operation for the longest period of time possible.
3. Maintain the equipment so that it always operates at the maximum possible efficiency.
4. Prolong the useful life of the equipment.

Preventive Maintenance Operations

The actual work performed during the application of the preventive maintenance schedule items is divided into six types of operations. Throughout this section, the lettering system for the six operations is as follows:

F—Feel	C—Clean
I—Inspect	A—Adjust
T—Tighten	L—Lubricate

a. Feel (F). The "Feel" operation is used most extensively to check rotating machinery (such as blower motors, drive motors, and generators) for over-heated bearings. "Feeling" indicates the need for lubrication or the existence of some other type of defect requiring correction. Normal operating temperature is that which will permit the bare hand in contact with the motor-bearing cover for a period of 5 seconds without feeling any discomfort. The "Feel" operation also is applied to a few items other than rotating machinery; the "Feel" operation for these items is explained in the discussion of each specific item.

Note: It is important that the feel operation be performed as soon as possible after the shutdown, and always before any other maintenance is done.

b. Inspect (I). "Inspection" is probably the most important of all the preventive maintenance operations. If more than one man is available to do this work, choose the most observant, for careful observation is required to detect defects in the functioning of moving parts and any other abnormal conditions. To carry out the "Inspection" operation most effectively, make every effort to become thoroughly familiar with normal operating conditions and to learn to recognize and identify abnormal conditions readily.

"Inspection" consists of carefully observing all parts in the equipment. Notice such characteristics as their color, placement, and state of cleanliness. Inspect for the following conditions:

(a) Overheating, as indicated by discoloration, blistering or bulging of the part or surface of the container; leakage of insulating compounds; and oxidation of metal contact surfaces.

(b) Placement, by observing that all leads and cabling are in their original positions.

(c) Cleanliness, by carefully examining all recesses in the units for accumulation of dust, especially between connecting terminals. Parts, connections, and joints should be free of dust, corrosion, and other foreign matter. In tropical and high-humidity locations, look for fungus growth and mildew.

(d) Tightness, by testing any connection or mounting which appears to be loose, by slightly pulling on the wire or feeling the lug or terminal screw.

c. Tighten (T). Any movement of the equipment caused by transportation or by vibration from moving machinery may result in loose connections which are likely to impair the operation of the set. The importance of firm mountings and connections cannot be overemphasized; however, *never* tighten screws, bolts, and nuts unless it is definitely known that they are loose. Fittings that are tightened beyond the pressure for which they were designed will be damaged or broken. When tightening, always be certain to use the correct tool in the proper size.

d. Clean (C). When the schedule calls for a "Cleaning" operation, it does not mean that every item which bears that identifying letter must be cleaned each time it is inspected. Clean parts only when inspection shows that it is necessary. The "Cleaning" operation to be performed on each part is described later on.

e. Adjust (A). Adjustments are made only when necessary to restore normal operating conditions. Specific types of adjustment are described later.

f. Lubricate (L). Lubrication means the addition of oil or grease to form a film between two surfaces that slide against each other, in order to prevent mechanical wear from friction. Generally, lubrication is performed only on motors and bearings.

Note: When a part is suspected of impending failure, even after protective maintenance operations have been performed, immediately notify the person in charge who will see that the condition is corrected by repair or replacement before a breakdown occurs.

Suggested List of Tools Necessary for Relay and Commutator Maintenance

A number of items on the preventive maintenance schedule require work of a special and somewhat delicate nature. This work includes cleaning and repairing relay contacts, cleaning plugs and receptacles, polishing commutators, and adjusting motor and generator brushes. To do the work properly, special supplies and specially constructed tools are needed. A suggested list is given below:

Nonmagnifying dental mirror.
Cleaning brush, 2-inch.
Canvas-cloth strip.
Sandpaper strip, fine.
Sandpaper strip, semifine.

Crocus-cloth strip.
Small relay crocus-cloth stick.
Relay-contact burnishing tool.
Fine-cut file.
Brush seating stone.
Commutator polishing stone.
Canvas-cloth stick.
Crocus-cloth stick.
Sandpaper stick.
1 Brush, cleaning, 1-inch.
1 Brush, cleaning, 2-inch (2).
1 Carbon tetrachloride, quart can.
2 Cement, household, tube.
1 Cloth, canvas, 2 x 4-feet.
1 Cloth or canvas, strip, 2 x 6-inch, cut from sheet (3).
1 Cloth, lint-free, package.
6 Crocus-cloth, sheets.
1 Crocus-cloth, strip, ¾ x 6-inch, cut from sheet (6).
1 File, small, fine cut.
1 Lubricant, Vaseline, container.
1 Mirror, nonmagnifying dental.
6 Sandpaper sheets, #0000.
6 Sandpaper sheets, #00.
1 Sandpaper, #0000, ¾ x 6-inch, cut from sheet.
1 Sandpaper strip, #00, ¾ x 6-inch, cut from sheet.
1 Stick, crocus-cloth, large.
1 Stick, special, canvas-covered.
1 Stick, special, crocus-cloth stick for relays, small.
1 Stick, special, sandpaper covered.
1 Stone, commutator polishing stone.
1 Stone, brush seating stone.
50 Tags, small marker.
1 Tool, relay contact burnishing.

Construction for Relay and Commutator Tools

Crocus-cloth, canvas-cloth, and sandpaper sticks are constructed in the following manner:

1. First prepare a length of wood 3¾ inches long, ⅜ inch wide, and 1/16 inch thick or less. Cut one piece of crocus cloth 2½ inches long and 1 inch wide.

2. Fold the crocus cloth as in Fig. 17-1 (A) and cement it to the stick. Note that both sides of the stick are covered. Place the stick in the vise, press it and wait until the cement hardens. Cut off the piece of crocus cloth which extends over the edge of the stick.

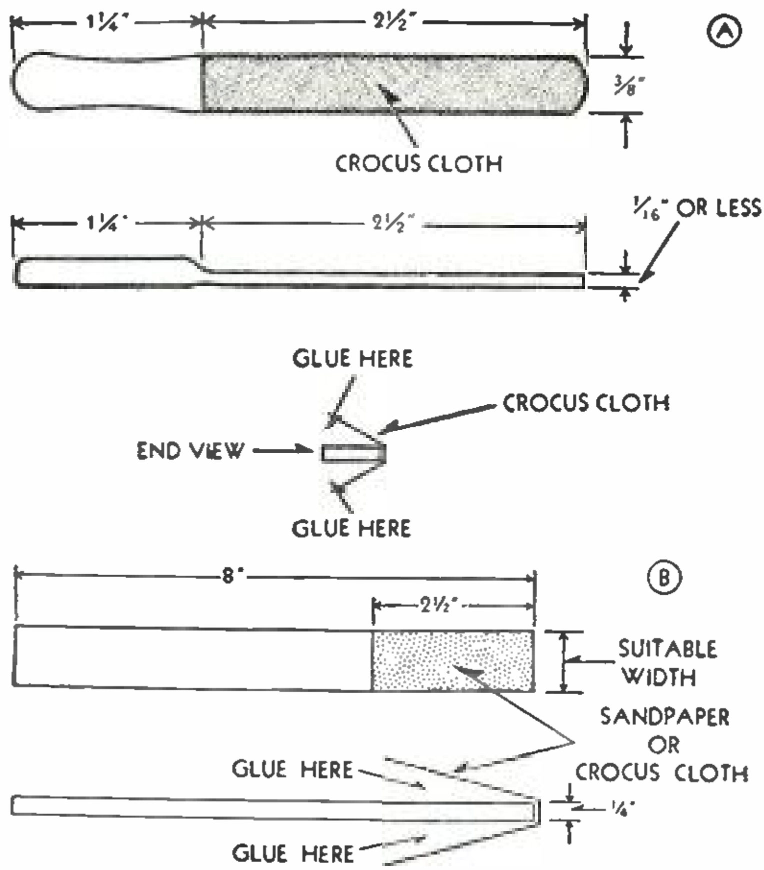


Fig. 17-1. The crocus-cloth stick (A) is used for cleaning relay contacts and the one in (B) is for cleaning motor or generator commutators.

3. Obtain three pieces of wood which measure 8 inches long, 1 inch wide, and approximately ¼ inch thick. Cut one piece of crocus cloth, one piece of #0000 sandpaper, and one piece of canvas cloth, each 5¼ inches long and 1 inch wide.

4. Fold the long, narrow pieces of crocus cloth, sandpaper, and canvas cloth as shown in Fig. 17-1 (B) and cement one of them to each of the three sticks. Note that in this case the fold is over one end of the stick rather than over the sides. Place the sticks in the vise, press, and wait until the cement hardens.

Use and Care of Tools

Proper care of tools is as necessary as proper care of radio equipment. Any effort or time spent in caring for tools is worth while. Clean them when necessary and always replace them so that they are easily accessible. The following information will be helpful in using and caring for the tools listed below.

a. Crocus-Cloth Stick. The crocus-cloth sticks are used to clean contacts of relays in the radio equipment.

b. Large Commutator Sticks. Commutator sticks with covering of sandpaper or canvas are used for cleaning commutators of electric motors and generator sets.

c. Commutator Dressing Stone. The dressing stone is used only in case of emergency to dress a commutator or motor generator.

d. Brush Seating Stone. The seating stone is used when a set of new brushes is installed in alternators or exciters. Only a very limited application of the seating stone is required to seat the average set of brushes.

e. Electric Soldering Iron. The use of the soldering iron is generally known. Remember to keep the tip properly tinned and shaped.

f. Allen Wrenches. Allen wrenches are used to tighten or remove the Allen setscrews on fan pulleys, motor pulleys, etc. These are small wrenches and should be kept in the cloth bag provided for that purpose. After use, wipe them off with an oily rag, replace them in the bag, and restore them to the tool box.

g. Diagonal-Cutting Pliers. Diagonal pliers are used to cut copper wire (no larger than No. 14) when working in small places. Do not cut iron wire with the diagonals.

h. Gas Pliers. Gas pliers are used to hold round tubing, round studs, or any other round metal objects that do not have screw driver slots or flat sides for wrenches.

i. Long-Nose Pliers. Long-nose pliers are used to hold and dent small wires and to grip very small parts. They are generally used around delicate apparatus.

j. Adjustable End-Wrenches. Adjustable end-wrenches are designed to remove or hold bolts, studs, and nuts of various sizes. Keep the adjusting-nut free from dirt and sand and oil them frequently.

k. Nut-Driver Wrenches. Nut-driver wrenches are used to remove nuts of various sizes. Choose a wrench that fits the nut snugly.

l. Screw Drivers. Screw drivers of different sizes are important tools and must be kept in good condition. Select the proper size for the job to be done. Never force a screw; if undue resistance is felt, examine the threads for damage and replace the screw if necessary.

m. Shorting Bar. The shorting bar must be constructed at the station. Obtain a piece of wood about 15 inches long and 1 inch thick. Fasten a piece of copper or brass rod or tubing securely to one end of the stick in such a manner that the rod extends 12 inches beyond the end of the stick. Solder a piece of heavy flexible wire about 18 inches long to the metal rod at the point where it is fastened to the stick and attach a heavy clip to the free end of the wire. When using the shorting bar, always attach the clip to a good ground connection BEFORE making contact with the terminal to be grounded.

Vacuum Tubes

The purpose of tube maintenance is to prevent tube failures caused by loose or dirty connections and to maintain the tubes in a clean operating condition at all times. Certain types of vacuum tubes, especially those used in high-voltage circuits, operate at high temperatures. Careless contact with the bare hands or arms causes severe burns. Sufficient time must be allowed for the tubes to cool before handling.

Maintenance of vacuum tubes involves making minor adjustments and cleaning. Tubes requiring the most frequent maintenance are those used in high-voltage circuits. Because of their high operating potentials, these tubes require more frequent inspection and cleaning than tubes used in low-voltage circuits. Loose coupling at the terminals of high-voltage tubes will result in the terminals becoming pitted and corroded. Loose connections cause poor electrical contact and lower the operational efficiency of the unit in which they are employed.

Maintenance of vacuum tubes should be applied only when necessary. Too frequent handling may result in damage to the tube terminals and connections. As a rule, vacuum tubes need little maintenance; therefore, when the program calls for maintenance, but inspection shows that the tubes do not require it, the operation should be omitted. It is advisable, however, to clean the glass envelopes of the tubes and remove dust or dirt accumulations surrounding their immediate areas. The *object* of the maintenance program is to maintain the tubes free from dirt, oil deposits, and corrosion.

Vacuum tubes for maintenance purposes are divided into two groups:

(1) Transmitting-type tubes.

(2) Receiving-type tubes.

Maintenance procedures required for vacuum tubes differ according to types. Certain maintenance operations that must be performed on transmitting-type tubes may be omitted in the maintenance of receiving-type tubes. Transmitting-type tubes are those used in transmitters, modulators, and high-voltage rectifier units. Because of their physical construction they require careful inspection and cleaning during maintenance.

Five procedures are required to the performance of maintenance of vacuum tubes: feel, inspect, tighten, clean, and adjust. The procedures involved depend on the type of tube being maintained. Transmitting tubes may require the application of the above-mentioned procedures, while the procedures required for receiving tubes are limited by tube types.

Maintenance Procedures

The following procedures should be employed for the maintenance of vacuum tubes:

Caution: Discharge all high-voltage capacitors before performing any maintenance operations. Avoid burns by allowing sufficient time for tubes to cool before handling.

Feel (F). (1) This operation should be applied only to high-voltage tubes, such as those used in transmitters, modulators, and high-voltage rectifier units.

Note: The following operations should be performed 5 to 10 minutes after power has been removed from the tubes.

(2) Feel the grid, plate, and filament terminals of the tubes for excessive heat. Practice will determine the temperature to be accepted as normal. For example, when two grid terminals are felt, one should not be warmer than the other. Excessive heat at terminals indicates poor connections.

Inspect (I). This maintenance operation is applicable to all types of vacuum tubes and should be performed after the tubes have had sufficient time to cool.

(1) Inspect the glass or metal envelopes of tubes for accumulations of dust, dirt, and grease. Inspect the tube caps and connector clips for dirt and corrosion. Inspect the complete tube assembly and socket for dirt and corrosion. Check the tube caps to determine whether any are loose. On glass tubes, check the glass envelope to determine whether or not it has become loosened from the tube base. Replace tubes which have loose grid caps or envelopes when these

faults are discovered. If replacement is impossible, do not attempt to clean or handle the tube, operate the tube as it is, providing that its operation is normal. Enter the tube condition in the log so that replacement can be made at the earliest possible time.

(2) Examine the spring clips that connect to the grid plate, and filament caps for looseness. Also examine all leads connected to these clips for poorly soldered or loose connections. These leads should be free of frayed insulation and broken strands. When removing clips from loosened grid caps, extreme care must be exercised, particularly if corrosion exists. Never try to force or pry a grid clip from the grid cap of a tube as damage to the tube or grid cap may result. If the grid cap is loose and it is necessary to remove the grid clip, first loosen the tension of the clip by spreading it open; then gently remove (do not force) the clip from the tube cap.

(3) Inspect the tubes to be sure they are secure in their sockets. Certain types of receiving tubes used are mechanically fastened with tube spring locks; others have sockets in which the tube itself is locked in place. Inspect by turning the tube in clockwise direction in its socket until it is locked in place. This type of socket is generally used for the transmitting-type tubes. However, the firmness with which the tube is held in place depends upon the tension of the terminals in the socket. These terminals are of the spring type (contact springs) and must have sufficient tension to make good contact against the tube prongs. The tension can be tested by grasping the tube and turning it first counterclockwise and then clockwise to its original position. If the tube seems to snap into place as it is turned, the spring tension of the socket terminals is firm enough; however, if the tension seems weak, they may be tightened or adjusted as explained in the tube maintenance procedure under "Adjust."

(4) Inspect all metal tubes for signs of corrosion and looseness of mounting. Many receiving-type tubes have keyways in the center of the tube bases. These keyways sometimes become broken, and have a tendency to loosen the tube in the socket. Do not attempt to replace tubes that have broken keyways unless it is absolutely necessary to do so, and it is possible to replace the tube correctly in its proper position. Inspect the tube sockets of metal tubes for cracks or breaks. Do not force metal tubes into their sockets. If they are hard to replace, examine the tube pins for signs of corrosion or solder deposits.

Tighten (T). (1) In performing this operation, take care not to overtighten tube sockets, tube clamps, and tube socket insulators.

Porcelain sockets and stand-off insulators crack due to heat expansion if they are excessively tightened. Do not overtighten them. Care should be taken when tightening the tube caps of high-voltage tubes. Use the proper screw driver or tool; if the tool should slip it may fall against the glass envelope of the tube and ruin a perfect tube.

(2) Tighten all tube connections, terminals, sockets, and stand-off insulators which were found loose during the inspection procedure. When tightening tube sockets having stand-off insulators, determine before tightening whether the fiber washers between the socket and the stand-off insulators are intact. If these fiber spacers are cracked or missing, replace them before tightening the tube socket. Tightening the socket without these spacer washers breaks or cracks the porcelain-tube socket.

Clean (C). In the performance of this item, clean only where necessary. Do not remove tubes for cleaning purposes unless it is impossible to clean them in their original positions. If the tube must be removed, exercise care in doing so. Do not attempt to clean the envelopes if they are located in an out-of-the-way place; in this case remove them for cleaning. When tubes are removed for cleaning, replace them immediately afterward. Do not leave them where they may be broken.

(1) Clean the entire tube assemblies with a clean dry cloth if the glass envelope is excessively dirty. Wipe the glass envelope with a damp cloth moistened in water. Polish after cleaning with a clean dry cloth. Do not wipe metal tubes with a cloth moistened in water, as this causes the metal body of the tube to rust. Use a cleaning agent if the tube is excessively dirty because of oil deposits. Generally, metal tubes with oil deposits on their envelopes can be cleaned successfully by polishing dry with a clean dry cloth. The oil film remaining on the metal body of the tube prevents the tube from rusting. To remove oiliness, corrosion, or rust from tube envelopes, moisten a clean cloth with cleaning agent and clean the area affected until it is clean. Wipe dry with a clean dry cloth.

(2) Clean the grid and plate caps, if necessary, with a piece of #0000 sandpaper, or crocus cloth. The paper should be wrapped around the cap and gently run along the surface. Excessive pressure is not needed; neither is it necessary to grip the cap tightly. Clean the caps completely before replacing them on the tube terminals if corrosion is noted on the grid or plate caps.

(3) When the tube sockets are cleaned and the contacts are acces-

sible, fine sandpaper should be used if corrosion is present on the contacts. Clean the contacts thoroughly after sandpapering. Clean all areas surrounding tube sockets with a brush and a clean dry cloth; this prevents dust and dirt from being blown back on the tube envelopes when the unit is put back into operation.

Adjust (A). When performing this operation, care must be taken to arrange all leads and terminals to correspond as closely as possible with their original positions.

(1) Adjust all leads and tube connections. Check to determine if the leads are resting on the glass envelope of the high-voltage tubes; if they are, redress the leads so that proper spacing is obtained. Examine all leads connecting to the tube caps. These should not be so tight that they barely reach the caps of the tubes. If this condition is found, redress these leads so that enough "play" is obtained. Adjust all grid clamps so that the proper tension is obtained. To increase the tension of tube clamps, close the spring clamps slightly with a pair of long-nose pliers until the proper tension is obtained. Do not flatten the clamps.

(2) Tube sockets used for transmitting-type tubes should be adjusted if the tube is found loose in its mounting. The terminals of these sockets are spring-tensioned so that they may be adjusted to increase the pressure against the tube pins. To adjust these contacts, simply bend them toward the center on the socket until the correct tension is obtained. Do not apply too much pressure to the spring contacts; they may be broken from their mountings in the porcelain socket.

(3) Any difficulty in removing or inserting metal tubes can be remedied easily. Remove the metal tube and examine the tube pins to determine if solder or corrosion has accumulated on the pins. Remove solder deposits with a penknife; then polish the pins with fine sandpaper. Do not use a soldering iron to remove solder deposits; this makes them worse, as the solder is built up on the pins rather than removed. To remove corrosion, use fine sandpaper, but never use it unless it is absolutely necessary. Saturate a small piece of cleaning cloth with light lubricating oil or petroleum jelly, and wipe the tube pins. Remove the excess oil from the pins by wiping them almost dry with a clean dry cloth. If these procedures are followed, no difficulty will be experienced in removing or reinserting the metal tube into its socket.

Caution: Do not force metal tubes into their sockets. Do not pry or "wiggle" them loose, since this damages the prongs of the socket and results in intermittent operation of the unit in which they are located.

Capacitors

High-Voltage Capacitors. High-voltage capacitors, because of their high operating potentials, must be kept clean at all times to prevent losses and arcing. Dirt, oil deposits, or any other foreign matter must not be allowed to accumulate on the high-voltage terminals of these capacitors. All leads and terminal connections must be inspected periodically for signs of looseness and corrosion, and the porcelain insulators inspected for cracks or breaks.

Low-Voltage Capacitors, Oil-Filled. Low-voltage oil-filled capacitors require the same care as those of the high-voltage type, although the frequency of the maintenance operation is not so critical. The terminals and connections of these capacitors should be given the same careful inspection as those of the high-voltage types. The leads of these capacitors are not as rugged as those used on the high-voltage capacitors and should be inspected more closely for poorly soldered connections.

Tubular Capacitors. These capacitors are of the low-voltage paper type and are generally used in low-voltage circuits for coupling and bypassing. They should be inspected and cleaned whenever the chassis in which they are located is removed for maintenance. The only maintenance requirement for these capacitors is inspection of the tubular body of the capacitor for bulging, excessive swelling of the capacitors, and for signs of wax leakage. The terminal leads (pigtail type) of the capacitors are inspected for firmness of contact at their respective points of connection. Never use a cloth to clean this type of capacitor, as damage to the surrounding circuits may result. These capacitors are easily cleaned with a small, soft brush. All dirt and dust are brushed from the body of the capacitor and the surrounding area.

Mica Capacitors. Mica capacitors require very little maintenance other than being kept free from dust and oil. Two types of mica capacitors are generally used: the high-voltage and the low-voltage type. The low-voltage types are inspected whenever the chassis of the unit in which they are located is being maintained. The capacitors are inspected for cracked body conditions caused by excessive heat, while their leads (pigtail type) are inspected for firmness of contact at their respective points of connection. The high-voltage types, however, require terminals because of their high operating potentials. These terminals must be inspected for tightness and corrosion, firmness of mounting, and body conditions. The body of these capacitors is of a ceramic material and care must be exercised when tightening the mountings of these capacitors. The bodies of the capacitors are easily kept clean with a dry clean cloth. For satisfactory operation the terminals must be free from dirt and corrosion at all times. Take care when tightening the terminals of these capacitors, as excessive pressure damages or cracks the ceramic case where the terminals are coupled to the body of the capacitors.

Trimmer Capacitors. In very damp climates, trimmer capacitors must be inspected often. Dampness, if allowed to accumulate on the plates of the capacitors, results in erratic operation of the unit in which the capacitors are used. In certain cases where high voltage is used, serious damage to the capacitors results. A minute amount of moisture or a tiny bead of water is all that is necessary to short-circuit the plates of the capacitor and cause abnormal operation. When such conditions are encountered, the capacitor must be thoroughly dried by the heat process which requires the use of a small portable heater. A cleaning cloth used to dry the plates of the capacitors may throw the plates out of alignment when the cloth is inserted between them. In extreme cases where the plates of the capacitors are very closely spaced, use a magnifying glass to locate the exact position of the moisture beads existing between the plates. Due to the sheen of the capacitor plates, very minute particles of moisture cannot always be detected by the naked eye.

Maintenance Procedures for Capacitors.

Caution: To avoid severe electrical shock in case of bleeder failures, *discharge* all high-voltage capacitors before maintenance.

Feel (F). Feel the terminals of the high-voltage filter capacitors. These should be fairly cool. Excessive heat probably indicates losses due to loose, dirty, or corroded terminal connections. Feel the sides of oil-filled and electrolytic capacitors. These should be cool or slightly warm. If they are very warm or hot, the condition indicates excessive internal leakage. Capacitors in this condition are subject to failure at any time and should be reported for immediate replacement.

Inspect (I). Inspect the general condition of all capacitors regardless of type. Inspect for broken, frayed, or loose terminals, leads, and connections. Inspect the condition of the terminals of the high-voltage capacitors. Check these for dirt, corrosion, and looseness. Inspect the body of the capacitors for excessive signs of bulging and oil leakage.

Inspect the plates of the tuning capacitors for dirt and corrosion. Check all capacitor shafts, bushings, bearings, and couplings for looseness or binding.

Tighten (T). Tighten all loose terminals, connections, and terminal leads on all types of capacitors. Tighten all capacitor mountings and stand-off insulators. Tighten all loose shaft couplings and bushings.

Clean (C). Special attention should be given to all high-voltage capacitors to insure that they are not only kept clean, but are free from moisture. Thoroughly clean the insulators, terminals, and leads of high-voltage capacitors. When extremely damp, due to high humidity, these capacitors frequently have to be wiped dry with a clean, absorbent cloth to prevent arc-overs and breakdown of insulation. Remove terminals that appear to be either corroded or dirty; also remove those causing power losses due to high-resistance connections. Clean them with a crocus cloth which is either dry or moistened with cleaning fluid. Polish the terminals dry after cleaning with a clean, dry cloth. Replace all connections after cleaning, making certain that good electrical contact is obtained. The low-voltage capacitors require little attention. However, all insulated bushings and supports should be kept clean and free from foreign matter.

Adjust (A). Adjust all leads if necessary. This requires the redressing of leads which may have been dislocated during the maintenance procedure. If capacitor leads are stretched too tightly, redress or replace them until the correct lead placement is obtained.

Resistors

Resistors may be divided for maintenance purposes into two groups: the first group consists of those resistors easily detachable and known as *ferrule-type resistors;* the second group includes those whose terminals are soldered and are known as *pigtail-type resistors.*

a. Ferrule-Type Resistors.

Caution: Do not touch power resistors immediately after the power has been shut off. They are usually hot, and severe burns may result.

Feel (F). The springiness of ferrule clips may be ascertained when removing the ferrule-type resistor. Insufficient *pull* at the clip may be an indication of a loose connection and poor electrical contact.

Inspect (I). It is important to inspect all types of resistors for blistering or discoloration, for these are indications of overheating. Inspect the leads, clips, and metalized ends of the resistors and adjacent connections for corrosion, dirt, dust, looseness, and broken strands in the connecting wires; also inspect the firmness of mounting.

Tighten (T). Tighten all resistor mountings and connections found loose. If the tension at the end clips has decreased, it is common practice to press the clip ends together by hand or with a pair of pliers. The hand method is preferred because the pliers may bend the clip or damage the contact surface.

Clean (C). Dirty or corroded connections of ferrule-type resistors can be cleaned by using a brush or cloth dipped in cleaning fluid. If the condition persists, use crocus cloth moistened with cleaning fluid. It may be necessary to sandpaper the resistors lightly with fine grade sandpaper, such as #0000. Always wipe clean with a dry cloth before replacing them. Vitreous resistors connected across high voltage should be kept clean at all times to prevent leakage or flashovers between terminals. They should be wiped clean with a dry cloth or a cloth moistened with cleaning fluid. If cleaning fluid is used, the resistors must be polished with a dry clean cloth.

Pigtail-Type Resistors. Maintenance of pigtail-type resistors is limited to an inspection of soldered connections. Such connections may break if the soldering is faulty or if the resistors are located in a place subject to vibration. The recommended practice is to slide a small insulated stick lightly over the connections and to inspect them visually for solidity. If connections are noticeably weak or loose, they should be re-soldered immediately. Discolored or chipped resistors indicate possible overloads. Although replacement is recommended, resistors in this condition have been known to last indefinitely. The pigtail-type connections should be dusted with a brush or with an air blower if available.

Fuses

A fuse consists of a strip of fusible metal inserted in an electric circuit. When the current increases beyond a safe value, the metal melts, thus interrupting the current. Fuses vary in size and rating depending upon the circuits at which they are used. Some are designed to carry currents in milliamperes. Being very rapid in action, they protect the equipment from overloads and damage. Two types of fuses are used: renewable and nonrenewable. The first type is designed so that the fuse link, or element contained within the fuse cartridge, may be removed and replaced when blown. The second type, however, is constructed so that the fuse element is permanently sealed within the fuse housing. When a fuse blows, an attempt must be made to determine the reason for its failure, and to make corrections, if possible, before a new fuse is installed; then the complete fuse assembly must be replaced.

Renewable Type. The renewable type fuse assembly consists of a housing or cartridge of insulating material with a threaded metal cap (ferrule) at each end. The fuse element or link, as a precaution against damage, is placed inside the cartridge or housing and it is held in position by the two end caps, or ferrules. When a fuse is placed in service, the two ends of the fuse cartridge are slid into spring contacts mounted on the fuse block. This places the fuse in the circuit to be protected.

Nonrenewable Type. When nonrenewable fuses are blown, they must be discarded. Certain types of nonrenewable fuses are removed by unscrewing and withdrawing the cap screws that hold them in place. When removed, the fuse and cap screw are separated by pulling apart. The glass fuses are easily removed for inspection. Care must be taken to see that the fuse end and holding clips are kept clean and tight . If they are not, overheating will result and make replacement necessary.

Inspect (I). Inspect the fuse caps for evidence of overheating and corrosion. Inspect the fuse clips for dirt, loose connections, and proper tension.

Tighten (T). Tighten the end caps, the fuse clips, and connections to the clips on replaceable fuses if they are found to be loose. The tension of the fuse clips may be increased by pressing the sides closer together. Fuse caps should be hand-tightened only. Excessive tightening results in difficulty in removing them when required.

Clean (C). Clean all fuse ends and fuse clips with fine sandpaper when needed; wipe with a clean cloth after cleaning. If it becomes necessary to use a file to remove deep pits in the clips, fuse ends, or contacts, always finish up with fine sandpaper in order to leave a smooth contact surface. As a final step, wipe the surface clean with a clean dry cloth.

Bushings and Insulators

Bushings and insulators are extremely important elements in electric circuits, especially when located in high-voltage circuits where insulation breakdown is most common. Most of the high-voltage insulators are constructed of ceramic material with highly glazed surfaces.

Caution: Exercise extreme care when working near these insulators. They are easily chipped or broken.

Inspect (I). Thoroughly inspect all high-voltage insulators and bushings for moisture, dust, and other accumulated foreign matter. Unless they are both clean and dry, leakage or arc-overs will occur and damage them permanently. Check the chipped surfaces, hair line cracks, carbonized arc-over paths, and other surface defects that may make the insulator unserviceable. Insulators in this condition should be reported to the person in charge for replacement.

Tighten (T). Feed-through bushings, stand-off and other insulators should be tightened if found to have loose mountings or supports. Tighten these insulators with care because gaskets absorb only a small amount of pressure before breaking.

Clean (C). Cleaning operations are similar to those outlined for tubes. Use a clean cloth (dampened with cleaning fluid if necessary) to remove dust, dirt, or other foreign matter. Always polish with a dry, absorbent cloth after cleaning.

Relays

The various types of relays may be classified as follows: overload relays, time delay relays, and magnetic contactors. Relays require a certain amount of preventive maintenance, which must never be performed except when absolutely necessary. Certain types will be found to be completely encased in dustproof and moistureproof cases. These require little maintenance other than a periodic inspection.

Maintenance of relays requires that they be inspected periodically and preventive maintenance measures performed if necessary. The inspection procedure requires that the terminals be inspected for looseness, dirt, and corrosion. Contacts may have become loosened because of the jarring of the equipment during shipment. The contacts may become dirty or corroded due to climatic conditions where the equipment is being operated. Relay contacts must never be sandpapered or filed unless the operation is absolutely necessary for the normal operation of the relay unit. A relay is considered normal if:

(1) The relay assembly is free from dirt, dust, and other foreign matter.
(2) The contacts are not burned, pitted, or corroded.
(3) The contacts are properly lined up and correctly spaced.
(4) The contact springs are in good condition.

(5) The moving parts travel freely and function in a satisfactory manner. The solenoids of plunger type relays must be free from obstructions.
(6) The connections to the relay are tight.
(7) The wire insulation is not frayed or torn.
(8) The relay assembly is securely mounted.
(9) The coil shows no sign of overheating.

A relay is considered abnormal if it fails to meet any of the abovementioned requirements. The following are the maintenance procedures used in the maintenance of relay units.

Inspect (I). Inspect the relays, to determine abnormal conditions using the check list given above. If the contacts are not readily accessible, they may be examined with the aid of a flashlight and mirror. Many of the relays can be inspected and cleaned without being removed from their mountings or without being taken apart. Mechanical action of the relays should be checked to make certain that the moving and stationary contacts come together in a positive manner and that they are directly in line with each other. The armature or plunger mechanism should move freely without binding or dragging. Care should be taken during inspection not to damage or misalign the relay mechanism. Relays that require the removal of the cover for complete inspection may be found enclosed in glass, Bakelite, or metal cases. Relays must never be taken apart unless it is absolutely necessary. If they must be taken apart for maintenance purposes, care should be exercised in doing so. When disassembling relays, tag all leads as they are being removed. This insures that the proper leads are returned to their proper terminals after the maintenance procedure is completed.

Tighten (T). Tighten all loose connections and mounting screws found loose, but do not apply enough force to damage the screw or to break the part which it holds. Do not start screws with their threads crossed. If a screw does not turn easily, remove it and start again. Relay coils can be tightened by inserting, if possible, a small wooden or paper wedge between the coil and the core of the relay. This prevents chatter of the relay. Tighten any and all loose connections. Tighten also the mounting of the relay assembly, if it is found loose. When replacing glass or Bakelite covers over relay cases, take care not to overtighten the screw cap holding the glass or Bakelite cover over the relay assembly.

Clean (C). Clean the exterior of the relay with a dry cloth, if it is very dirty; clean with a cloth or brush dipped in cleaning fluid; then wipe the surface with a dry cloth. If loose connections are found, they should be inspected. If inspection reveals that the connections are either dirty or corroded, they should be removed and cleaned before tightening.

The relay service aid is a narrow piece of folded cloth or canvas. It serves a twofold purpose: it is suitable for polishing a clean surface, and it is used as a follow-up to a crocus cloth. It is also intended to remove grains of pumice which came off the crocus cloth and adhere to the contact surface. The cloth is used as shown in Fig. 17-2.

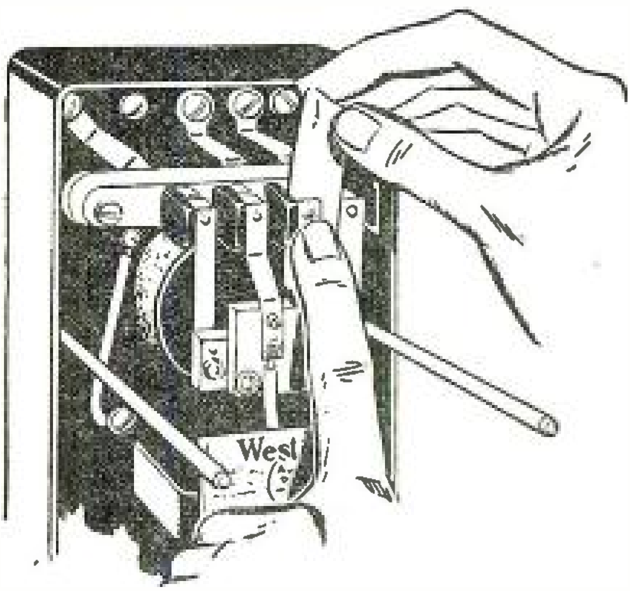


Fig. 17-2. Relay contact surfaces are polished by a narrow strip of cloth or canvas as shown in the sketch.

Cleaning Relay Contacts. The following information should be carefully studied. It instructs how relay contacts of various types should be cleaned.

Hard contacts. Hard alloy contacts are cleaned by drawing a strip of clean wrapping paper between them while holding them together. It may be necessary in some cases to moisten the paper with cleaning fluid. Corroded, burned, or pitted contacts must be cleaned with the crocus cloth strip or the burnishing tool as shown in Fig. 17-3.

Solid silver contacts. Dirty contacts. Dirty solid silver contacts are easily cleaned with a brush dipped in cleaning fluid. After being cleaned, the contacts are polished with a clean dry cloth.

Note: The brown discoloration that is found on silver and silver-plated relay contacts is silver oxide and is a good conductor. It should be left alone unless the contacts must be cleaned for some other reason. It may be removed at any time with a cloth moistened in cleaning fluid.

Corroded contacts: Dress the contacts first with crocus cloth, using either the stick or the strip of crocus material. When all of the corrosion has been removed, wipe with a clean cloth moistened in cleaning fluid and polish with a piece of folded cloth. Make certain that the shape of the contacts has not been altered from the original.

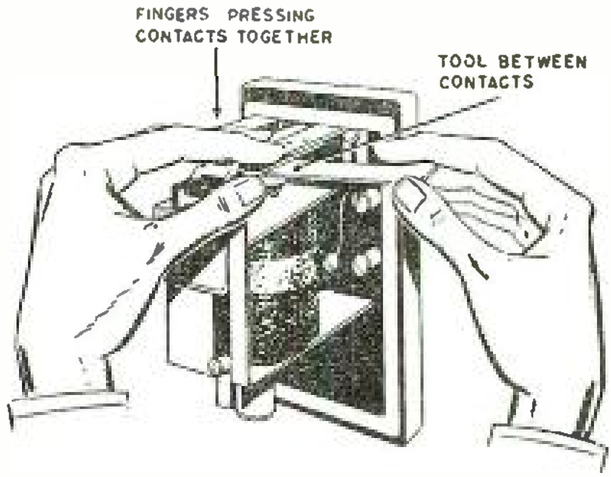


Fig. 17-3. Hard alloy contacts of a relay are cleaned by pulling a strip of clean wrapping paper between them while pressing the contacts together.

Burned or pitted contacts: Resurface the contacts, if necessary, with #0000 sandpaper, making certain that the original shape of the contacts is not changed. Next, smooth the surface of the contacts with crocus cloth until a high polish has been obtained. Wipe thoroughly with a clean cloth to remove the abrasive remaining on the contacts. When contacts are very badly burned or pitted and replacement is not available, the small fine-cut file and #0000 sandpaper should be used in keeping with instructions given later.

Silver-plated contacts. Dirty contacts: Dirty silver-plated contacts are cleaned with a cloth or brush dipped in cleaning fluid. After being cleaned, the contacts are polished with a dry cloth.

Corroded contacts: Dress first with crocus cloth, using either the stick or strip of crocus material. The work must be done very carefully not to remove an excessive amount of silver plating. When all of the corrosion has been removed, polish with a clean dry cloth. Make certain that the shape of the contacts has not been altered.

Burned or pitted contacts: Dress the contacts with crocus cloth until the burned or pitted spots are removed. This may require an appreciable amount of time and energy, but it is preferable to using a file or sandpaper. If it is found that the crocus cloth does not remove the burns or the pits, use the sandpaper tool very carefully. When sandpaper is used, it must be followed with crocus cloth to polish the contacts, and then wiped thoroughly with a cloth moistened in cleaning fluid. The contacts are then polished with a clean dry cloth.

Warning: Never use highly abrasive materials, such as emery cloth, coarse sandpaper, or carborundum paper for servicing relay contacts, as damage to the contacts will result.

Adjust (A). Adjust relay contacts after cleaning if necessary. The contacts should close properly when the plunger is hand operated. Adjust the relay springs if necessary. Do not tamper with the relay springs unless it is absolutely necessary. These springs are factory adjusted and maintain a certain given tension and rarely get out of adjustment. If the spring tension must be changed, exercise care when doing so. The adjustment of the current control relays is accomplished by setting calibrated knobs to the desired setting, or by turning a knurled adjustment sleeve which has a calibrated scale mounted adjacent to it. The adjustments should not be changed from their original factory setting except in cases of emergency. Overload relays must never be adjusted unless the person in charge has been notified, and has sanctioned the adjustment.

Shapes of Relay Contacts. Relay contacts are of varied shapes, as shown in Fig. 17-4 depending upon their size and application. In some

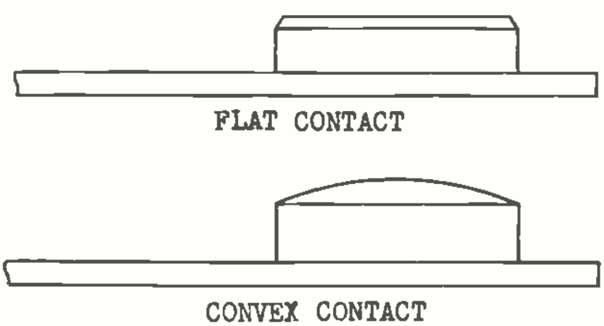


Fig. 17-4. The original shape of the contacts must be retained. This shape may be either flat or convex, as shown at the left.

instances, both contacts are flat; in others, one contact is convex while its mate is flat. The original shape of a contact must be retained during cleaning. If burning or pitting has distorted the contact so that it must be reshaped, the original shape must be restored. It is essential that the maintenance personnel familiarize themselves with all details of the relays by examining them while the relays are in good condition. In this way, they will be better prepared to do their work well.

Relay Servicing Tools and Their Use

To service the relay contacts, several types of tools are needed. Each of these has a special function, as described below.

The Burnishing Tool. This tool is used on relays which have extremely hard contacts made of palladium or elkonium. This tool is not a file. A contact should not be burnished unless it is found to be pitted or oxidized, and then not more than is necessary to restore a clean smooth surface. The original shape of the contact must be retained.

Small Fine-Cut File. This file is to be used only on the larger contacts when they have become very badly burned or pitted, and a replacement is not available. This tool is not to be used on silver-plated contacts, or on the contacts of the telephone-type relays. The file should not be used more than is necessary to remove the pit. The original shape of the contact must be preserved. After filing, #0000 sandpaper should be applied to the contact, and followed with crocus cloth to obtain a smooth finish on the contact surface. A clean dry cloth serves for final polishing.

The #0000 Sandpaper Stick. This tool is made in the same way as the crocus-cloth stick, except that sandpaper is used instead of crocus cloth. The use of sandpaper is limited, as is the use of the fine-cut file, to the treatment of badly burned or pitted contacts on the larger relays. Sandpaper is not used on silver-plated contacts, except under extreme circumstances, and when used should be followed with crocus cloth. All contacts should be polished after sanding, with a clean dry cloth.

Crocus Cloth. This maintenance aid is available in two forms—as a tool and as a strip of material. It serves a twofold purpose: it may be used to remove corrosion from all relay contacts, or it may be applied to the contacts following the use of the fine-cut file and #0000 sandpaper. Neither the file nor sandpaper leaves a finish smooth enough for proper relay operations. Use crocus cloth to polish the surface of the contact. The choice between the stick and the piece of cloth depends upon accessibility. If the location of the relay and the position of the contacts permit the use of the crocus-cloth stick, it should be used; otherwise, the strip of crocus cloth must serve. The crocus cloth and tool are used as illustrated in Figs. 17-2 and 17-3. In both cases the maintenance aid is inserted between the contacts and is drawn through them while the contacts are pressed together with the fingers.

Switches

For the purpose of maintenance, switches may be classified into two general groups: those whose contacts are readily accessible, and those whose contacts are completely encased. The basic maintenance operations of "Inspection," "Cleaning," "Adjusting," and "Lubrication" are applicable only to the first group. Because of the enclosed construction of the second group, no maintenance can be applied. The work is limited to a mechanical test of their operations.

Accessible Contact Switches. This group consists of knifeblade switches, start-stop push-button switches, and high-voltage shorting bars. With the exception of the shorting bars, all of these switches consist of blades which are mechanically inserted into spring contacts.

Inspect (I). Inspect all the terminal connections of each individual switch for tightness and cleanliness. The mounting of the switch should be checked for firmness. Operate the mechanism of the switch and see if the parts move freely. Observe the stationary spring contacts to determine whether they have lost tension and whether they are making good electrical contact.

Tighten (T). All loose mountings and connections should be tightened properly. If inspection shows that the fixed contacts have lost tension, tighten them with the fingers or pliers. Tighten every connection or terminal found loose.

Clean (C). If inspection shows that any terminal, connection, or section of the switch is dry, dusty, corroded, or pitted, clean the part by using a dry clean cloth. If the condition is more serious, moisten the cloth with cleaning fluid and rub vigorously. Surfaces which have been touched with the bare hands must be thoroughly cleaned with a cloth moistened in cleaning fluid, and then polished with a clean cloth. The points of contact with the moving blade are naturally those which most often show signs of wear. Examine these points very carefully to insure that both sides of each blade, as well as the contact surfaces of the clips, are spotlessly clean at all times. Crocus cloth moistened with cleaning fluid should correct this condition; however, if it is not corrected, #0000 or #000 sandpaper may be used. Always polish clean after the sandpapering operation.

Adjust (A). Some of the switches have a tendency to fall out of alignment because of loosening of the pivot. In most cases, tightening the screw on the axis of motion corrects this condition.

Lubricate (L). If binding is noted during inspection of the operation of the switch, apply a drop of instrument oil with a toothpick to the point of motion or rotation. Do not allow oil to run into the electrical contacts, as a film of oil may cause serious damage or a poor contact. Lubrication of switches is not recommended unless serious binding is noticed.

Nonaccessible Contact Switches. Under this heading are included all the remaining switches not discussed in the previous paragraph. Interlock switches, toggle switches, meter protective push buttons, and selector switches have been designed so that it is impossible to get at the contact without breaking the switch assemblies. The only maintenance possible is to check the operation of the switch assemblies and, if something abnormal is detected, to notify the person in charge immediately so that a spare may be obtained and a replacement made as soon as possible. Do not lubricate any of these switches under any circumstances.

Generators and Motors

Certain preventive maintenance procedures must be applied to these components if proper functioning and dependable performance are to be obtained. There are three principal cases that contribute to faulty operation of this type of equipment: accumulation of dirt, dust, or other foreign matter on the windings and moving parts of the equipment; lack of sufficient lubrication on bearings and other moving parts; and improper adjustments or damaged parts. Given proper maintenance care, motors and generators give long and efficient service. In addition to the techniques given in the following paragraphs, additional maintenance instructions covering certain motors or generators will be found in various items of the manufacturer's instruction books. Unless specifically mentioned, the maintenance techniques that follow apply to the motors and generators used in the transmitter.

Feel (F). The bearing and the housings should be tested by feeling them to determine overheated conditions. An accepted test, except in very hot climates, is to hold the bare hand in contact with the bearing or housing for a period of at least 5 seconds. If the temperature can be tolerated this length of time, the bearing temperature may be considered normal. Overheating may indicate lack of sufficient lubrication, a damaged bearing surface, or, in rare situations, an excessive accumulation of dirt within the field windings.

Inspect (I). Each motor and generator exterior, and any other visible parts, must be inspected for dirt and signs of mechanical looseness or defects. Wherever wires are exposed, see that all connections are tight and in good condition and that the insulation is not frayed. Inspect the motor ends for excess oil and the mounting for loose bolts. Wherever possible and practicable, feel the pulleys, belts, and mechanical couplings to insure that the proper tension or tightness is present.

Tighten (T). Any mounting, connection, or part found loose must be properly tightened. If any internal part such as a commutator segment or an armature coil appears loose, notify the person in charge and repair the part immediately or replace it at the first opportunity. Operation under these conditions will cause considerable damage in a very short period of time.

Clean (C). Carefully wipe the exterior, base, and mountings of each motor and generator with an oiled cloth in order to leave a thin, protective film of oil on the surfaces. If available, use an air blower, or hand bellows to blow the dust and dirt out when inspection shows that the windings are dusty or dirty.

If inspection of the commutator and brushes shows that cleaning is necessary, the accepted cleaning practice is as follows: lift or remove the most accessible brush assembly and press a piece of canvas cloth folded to the exact width of the commutator against the commutator; then run the motor for about 1 minute, exerting the necessary pressure. If the condition still persists because the commutator has been burned or pitted, use a piece of fine sandpaper (#0000), preferably mounted on the commutator cleaning stick, and, exerting the necessary pressure, rotate the motor for approximately 1 minute. Stop the motor and wipe around the commutator bars with a clean cloth. It may be necessary to polish the commutator with a piece of canvas, as explained in the first procedure. Identical maintenance procedures apply to slip rings.

Transformers and Choke Coils

Some transformers are enclosed in metal housings, others are external, but in all cases they are impregnated with insulating compound. As a result, similar maintenance techniques are applicable to all of them.

Inspect (I). Carefully inspect each transformer and choke for general cleanliness, for tightness in connections of mounting brackets and rivets, for solid terminal connections, and for secure connecting lugs. The presence of dust, dirt, and moisture between terminals of the high-voltage transformers and chokes may cause flashovers. In general, overheating in wax- or tar-impregnated transformers or coils, is indicated by the presence of insulating compound on the outside or around the base of each transformer or coil. If this condition is encountered, immediately notify the person in charge.

Tighten (T). Properly tighten mounting lugs, terminals, and rivets found loose.

Clean (C). All metal-encased transformers can be cleaned easily by wiping the outer casings with a cloth moistened with cleaning fluid. Clean the casing and the immediate area surrounding the transformer base. Clean any connections that are dirty or corroded. This operation is especially important on high-voltage transformers and coils. It is very important that transformer terminals and bushings on all types of transformers be examined and kept clean at all times.

Variacs

Variacs, as a rule, are built sturdily and are protected so that very little maintenance other than regular inspection is required.

Inspect (I). Carefully inspect the exteriors of the variacs for signs of dirt and rust. Inspect the mounting of each variac to determine whether it is securely mounted. Inspect all connections for looseness, corrosion, and dirt. Check the slip rings for signs of corrosion or dirt.

Clean (C). The perforated casing of each variac as well as the area surrounding the base must be cleaned regularly. If the slip rings need cleaning, dismount the variac and clean with a cloth moistened in cleaning fluid and then polish with a clean dry cloth. If the dirty condition persists, use crocus cloth and rub vigorously. Again polish with a clean cloth. Reassemble the variac; then reinstall it, reconnecting all terminals carefully.

Lubricate (L). If the variac shaft shows signs of binding or if it squeaks, apply a few drops of household oil to the front and rear bearings. Rotate the control shaft back and forth several times to insure equal distribution of the lubricant in the front and rear bearings.

Rheostats and Potentiometers

Rheostats and potentiometers fall into two main groups for maintenance purposes; those which have the resistance winding and the sliding contact open and accessible, and those which, by construction, have their inner parts totally enclosed. In the latter group, very little maintenance can be performed, since opening and removing the metal case may damage the unit.

Inspect (I). The mechanical condition of each rheostat must be inspected regularly. The control knob should be tight on the shaft. Inspect the contact arm and resistor winding for cleanliness and good electrical contact. Check the rheostat assembly and mounting screws for firmness; the sliding arm for proper spring tension; and the insulating body of the rheostat for cracks, chipped places, and dirt.

Tighten (T). Tighten carefully any part of the rheostat or potentiometer assembly found loose.

Clean (C). The rheostat or potentiometer assembly is easily cleaned by using a soft brush and then polishing with a soft clean cloth. If additional cleaning is needed, or if the windings show signs of corrosion or grease, the brush may be dipped in cleaning fluid and brushed over the winding and contacts. With a clean cloth, remove the film that remains after the cleaning fluid has evaporated. If the contact point of the sliding arm is found burned or pitted, it is good practice to place a piece of folded crocus cloth between the contact and the winding and then to slide the arm a number of times over the crocus cloth. When cleaning the winding, do not exert excess pressure, or damage will result.

Adjust (A). If the tension of the sliding contact is insufficient, an adjustment can be made with the long-nose pliers. Slight bending of the rotating piece in the proper direction restores the original tension.

Lubricate (L). Apply lubrication only when necessary; that is, when binding or squeaking is noticed. One or two drops of instrument oil applied to the bearings with a toothpick is sufficient. Since the slightest flow of oil into the winding or the sliding-arm contact may cause serious damage, lubrication should be applied very carefully and only on the bearings. Wipe off all excess oil.

Terminal Boards and Connecting Panels

Little preventive maintenance is required on terminal boards and connecting panels.

Inspect (I). Carefully inspect terminal boards for cracks, breaks, dirt, loose connections, and loose mountings. Examine each connection for mechanical defects, dirt, corrosion, or breakage.

Tighten (T). All clean terminals, screws, lugs, and mounting bolts found loose should be tightened properly. Use the proper rods for the tightening procedure and do not overtighten or the assembly may become cracked or broken.

Clean (C). If a connection is corroded or rusty, it is necessary to disconnect it completely. Clean each part individually and thoroughly with cloth or crocus cloth moistened with cleaning fluid. All contact surfaces should be immaculate for good electrical contact. Replace and tighten the connection after it has been thoroughly cleaned.

Air Filters

Air filters are placed in blowers and ventilating ducts to remove dust from the air drawn into and circulated through the ventilating system. Some filters are impregnated with oil and some are filled with cut strands of glass to facilitate the filtering action. The following procedures cover their maintenance:

Inspect (I). The filter should be inspected for any large accumulation of dirt and for lack of oil. Note whether the filter is mounted correctly and whether the retaining clips are in place. Improperly assembled filter elements or wall frames, allow unfiltered air to leak around the edges and thus permit dust to enter the ventilating system.

Tighten (T). Tighten the retaining clips if they are found loose, and readjust the filter in its mounting.

Clean (C). The filters are easily accessible and may be taken out after removal of the cover plate. The general procedure is, as follows: mark the outside of the filter before removing it from the air duct. Before washing it, tap its edges against the wall or on the ground to remove as much dirt as possible. Wash the filter in gasoline, using a brush to remove dirt from the steel wool. After the filter has been washed, place it face down on two supports. Allow it to drain and dry thoroughly before lubricating.

Lubricate (L). Lubricate or recharge the filter element by dipping it in a bath of oil. In temperatures about 20 F., use SAE-10 oil. Allow the filter to drain thoroughly, intake side down, before it is put into use. While the filter is draining, keep the filter away from places where sand or dirt is being blown through the air. Always replace a filter with its intake side facing the incoming air flow.

Cabinets

The cabinets which house the various components of the set are generally constructed of sheet steel.

Inspect (I). The outside and inside of each cabinet must be inspected. Check the door hinges (if any), the ventilator mountings, the panel screws, and the zero-setting of the meters. Examine the pilot light covers for cracks and breaks. Occasionally remove the covers and see whether the pilot light bulbs are secure in their sockets. Inspect the control panels for loose knobs and switches.

Adjust (A). Adjust the zero-setting of meters if found to be incorrect. Follow the specific instructions given below.

Clean (C). Clean each cabinet including the control panel, outside and in, with a clean dry cloth. Clean the meter glasses and control knobs with a clean dry cloth.

Lubricate (L). Door hinges and latches need little lubrication, but if inspection reveals that they are becoming dry, apply a small amount of instrument oil. All excess oil should be removed with a clean dry cloth.

Meters

Meters are extremely delicate instruments and must be handled very carefully. They require very little maintenance, but, because they are precision instruments, they cannot be repaired in the field. A damaged meter should be replaced with a spare; a defective meter returned to the maker for repair.

Inspect (I). Inspect the leads and connections to the meter. Check for loose, dirty, and corroded connections. Also check for cracked or broken cases and meter glasses. Since the movement of a meter is extremely delicate, its accuracy is seriously affected if the case or glass is broken, and dirt and water filter through. If the climate is damp, it is only a matter of time until enough moisture seeps through a crack to ruin the meter movement.

Tighten (T). Tighten all loose connections and screws. Any loose meter wires should be inspected for dirt or corrosion before they are tightened. The tightening of meter connections requires a special technique because careless handling can easily crack the meter case. To prevent breakage, firmly hold the hexagonal nuts beneath the connecting lugs while the outside nut is being tightened. This permits the tightening of the connection without increasing the pressure of the head of the stud against the inside of the meter case.

Clean (C). Meter cases are usually made of hard highly polished Bakelite, and can be cleaned with a dry cloth. If cleaning is difficult, the cloth should be dampened with cleaning fluid. Dirty connections may be cleaned with a small stiff brush dipped in the cleaning fluid or with a small piece of cloth dipped in the solvent. It should be emphasized that solvents do not remove dirt entirely from hard surfaces. Some of the dirt remains in a softened state and must be removed with a damp cloth. Corroded connections are cleaned by sanding them lightly with a very fine grade of sandpaper, such as #0000. After they are cleaned, the connections should be wiped carefully with a clean cloth.

Adjust (A). Normally, all meters should indicate zero when the equipment is turned off. The procedure for setting a meter to zero is not difficult. The tool required is a thin-blade screw driver. Before deciding that a meter needs adjusting, tap the meter case lightly with the tip of one finger. This helps the needle overcome the slight friction that sometimes exists at the pointer bearings and prevents an otherwise normal unit from coming to rest at zero. If adjustment is needed, insert the tip of the screw driver in the slotted screwhead located below the meter glass and slowly turn the adjusting screw until the pointer rests at zero. Observe following precautions: View the meter face and pointer full on and not from either side. Avoid turning the zero-adjust screw too far, as the meter pointer may be bent against the stop peg or the spring may be damaged. Zero adjustments should not be made for several minutes after shutdown.

Pilot Lights

Pilot lights are used to indicate that power has been applied to a circuit or that a circuit is ready for power to be applied. They are easily removed and replaced. The colored pilot light covers should be removed carefully, lest they be dropped and broken. The maintenance of pilot lights presents no special difficulty, but the following instructions are given for general guidance.

Inspect (I). Inspect the pilot light assembly for broken or cracked pilot light shields; loose bulbs; bulbs with loose bases; loose mounting screws; and loose, dirty, or corroded connections.

Tighten (T). Tighten all mounting screws, and resolder any loose connections. If the connections are dirty or corroded, they should be cleaned before they are soldered. Loose bulbs should be screwed tightly into their bases. Broken or cracked pilot light shields may sometimes be temporarily repaired by joining the broken or cracked pieces with a narrow piece of friction tape. Replace them as soon as possible; also replace broken or burned-out pilot light bulbs as soon as possible. While the removal of a bulb may sometimes be difficult, the process is made simple by folding a small piece of friction tape over the top of the bulb and pressing firmly from the two sides. After the tape is attached, the bulb can be unscrewed and removed from the socket. The socket connections are, of course, inspected while the bulb is out. A new bulb can be replaced with the fingers, but if difficulty is experienced, use friction tape to grip the glass envelope of the bulb.

Clean (C). The pilot light shield, the base assembly, and the glass envelope of the light bulb should be cleaned with a clean dry cloth. Clean accumulated dust or dirt from the interior of the socket base with a small brush. Corroded socket contacts or connections can be cleaned with a piece of cloth or a brush dipped in cleaning fluid. The surfaces are then polished with a dry cloth. Clean contacts and connections are important.

Plugs and Receptacles

There are two main types of plugs and receptacles used to interconnect the various components. The first type of plug is used with a coaxial line and consists of a metal shell with a single pin in the center insulated from the shell. When the plug is inserted into the receptacle, this pin is gripped firmly by a spring connector. There is a knurled metal ring around the plug which is screwed onto the corresponding threads on the receptacle; while the female part is in the plug. The insulation in these plugs is much heavier in order to withstand the voltage. The second type of plug is used for connecting multiconductor cables. The plug usually consists of a number of pins insulated from the shell which are inserted into a corresponding number of female connectors in the receptacle, although in some cases the plug has the female connectors in it and the male connectors are in the receptacle. This type of plug usually has two small pins or buttons which are mounted on a spring inside the shell and protrude through the shell. When the shell is properly oriented and placed in the receptacle, one of these pins springs up through a hole in the receptacle, firmly locking the plug and receptacle together. When it becomes necessary to remove the plug, the other pin is simply depressed and the plug removed. Connections between all plugs and their cables are made inside the plug shell. The cable conductor may either be soldered to the pin or there may be a screw holding the wire to the pin. Remove the shell if it is necessary to get at these connections for repair or inspection. Loosen the screws if there is a clamp holding the cable to the shell. In some cases, it is found that the shell and plug body are both threaded; then the shell may simply be unscrewed. Usually there are several screws holding the shell. These are removed and the shell is pulled off.

Inspect (I). (1) The part of the cable that was inside the shell for dirt and cracked or burned insulation.

(2) The conductor or conductors and their connection to the pins for broken wires; bad insulation; and for dirty, corroded, broken, or loose connections.

(3) The male or female connectors in the plug for looseness in the insulation, damage, and for dirt or corrosion.

(4) The plug body for damage to the insulation and for dirt or corrosion.

(5) The shell for damage such as dents or cracks and for dirt or corrosion.

(6) The receptacle for damaged or corroded connectors, cracked insulation, and proper electrical connection between the connectors and the leads.

Tighten (T). (1) Any looseness of the connectors in the insulation, if possible; if not, replace the plug.

(2) Any loose electrical connections. Resolder if necessary.

Clean (C). (1) The cable, using a cloth and cleaning fluid.

(2) The connectors and connections using a cloth and cleaning fluid. Use crocus cloth to remove corrosion.

(3) The plug body and shell using a cloth and cleaning fluid, and crocus cloth to remove corrosion.

(4) The receptacle with a cloth and cleaning fluid if necessary. Corrosion should be removed with crocus cloth.

Adjust (A). The connectors for proper contact if they are of the spring type.

Lubricate (L). The plug and receptacle with a thin coat of Vaseline if they are difficult to connect or remove. The type of plug with the threaded ring may especially require this.

Part 6

TECHNICALLY SPEAKING

INTRODUCTION

As has been mentioned several times in this handbook, it is not our purpose to duplicate or rewrite any of the already excellently presented technical phases of radio in other books. The content of this section is technical in nature, but is slanted primarily to allow a clearer insight of the why and wherefore of operating procedures as presented in the first four sections. In addition to this, there are a number of technical matters of outstanding interest to broadcast operators that have not previously been written in the language of the average technician who need not necessarily be a mathematical wizard. It is hoped that the following pages will prove helpful in presenting an understandable picture of the field of broadcast engineering to the operating personnel and to students of the broadcasting arts.

Chapter 18

CONTROL ROOM AND STUDIO EQUIPMENT

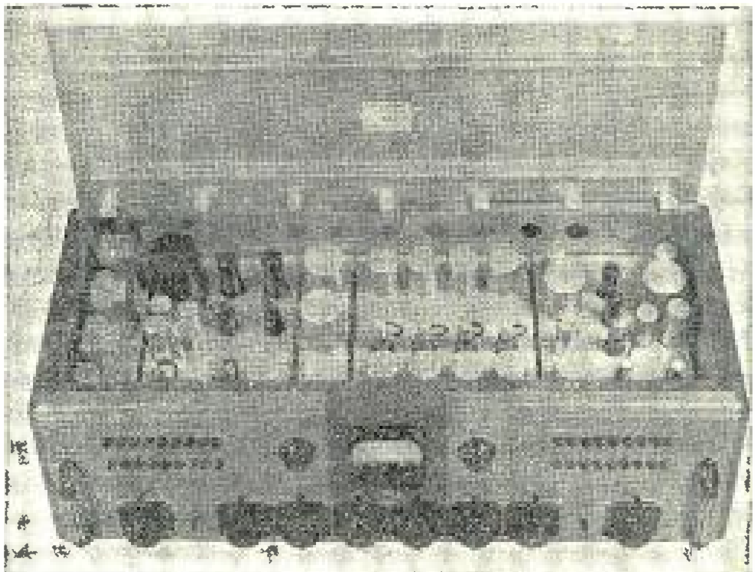
CONTROL-ROOM EQUIPMENT may become very complex in number of circuits and control functions, but is designed and installed to achieve a practical easily operated setup that allows foolproof switching and flexibility of functions. Briefly, the general requirements are as follows:

(a) Amplifiers for stepping up the minute electric energy produced in the microphone by the program sound waves.
(b) Switching and mixing arrangements to allow selection of proper program source and blending of microphone outputs for desired program "balance."
(c) Facilities for "auditioning" or rehearsing a program to follow.
(d) Terminations of inputs and outputs of all amplifiers on jack panels to allow rapid "rerouting" of the signal in case of trouble in any one amplifier or channel.
(e) Incoming and outgoing line terminations on jack panels to permit flexibility in receiving or transmitting the signal in any way desired.

Fig. 18-1 illustrates one type of commercial control-room console which contains all amplifiers and relays within the cabinet. The power supply comes in an external wall mounting unit. This console provides amplifiers, control circuits, and monitoring equipment necessary to handle two studios, announce booth microphone, two transcription turntables, control-room announce microphone, and six remote lines. In addition to this, means are provided for simultaneously auditioning or broadcasting from any combination of studios, turntables, or remote lines. The volume indicator is a standard vu meter which has an adjustable attenuator mounted on the panel to the right of the instrument allowing a 100% deflection of the pointer on the scale to be calibrated for +4, +8, +12, and +16 vu.

The technical layout of this speech input equipment is as follows:

Four preamplifiers connected to four of the six mixers on the panel in center position serve to amplify the outputs of the microphones. A 3-position key switch is in the input of the fourth preamplifier to allow its operation from a microphone in the studio, announce booth,

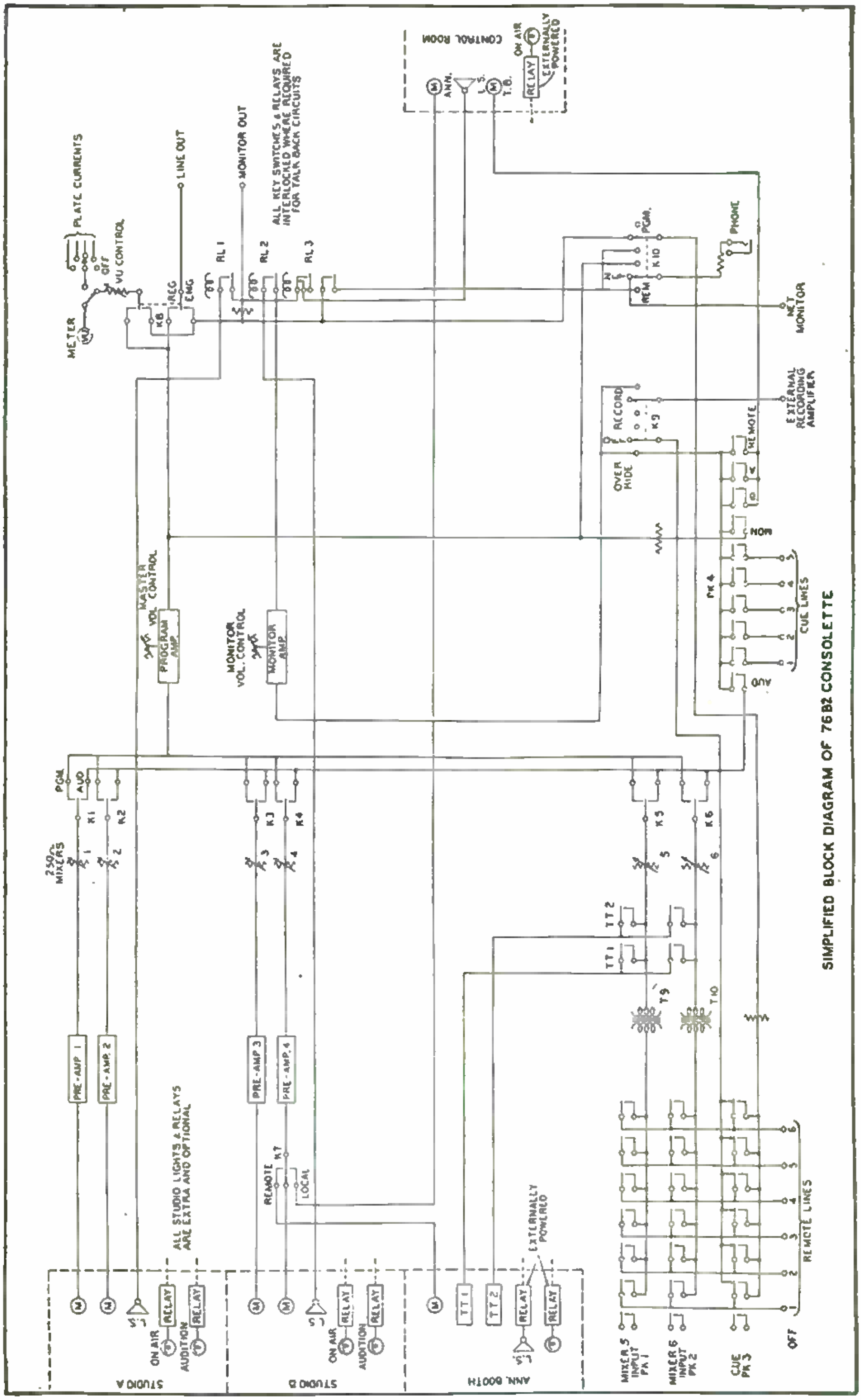


RCA Photo

Fig. 18-1. One type of commercial control-room console containing all amplifiers and relays within the cabinet.

or control room. The outputs of the mixers connect to lever keys to provide switching to the regular program amplifier for broadcasting or to the monitor amplifier for auditioning. When these key switches are operated they also serve to disconnect the studio loudspeaker to prevent feedback, and operate "on-air" light relays. The fifth and sixth mixers may be connected by means of push keys to any of six remote lines or the two turntables. Other push keys on the panel provide circuits for feeding the cue to remote lines and for bringing in monitoring circuits such as transmitter or master-control (where used) outputs. The monitoring amplifier may be used for the program amplifier in emergencies by operating the proper key. Means are also provided to supply power to the preamplifiers from the monitoring amplifier in case of power supply failure to the preamplifiers.

This is an example of the extreme flexibility and emergency provisions designed into control-room equipment. Fig. 18-2 is a simplified schematic diagram of a typical installation. The "Override-Record" switch permits a remote operator to call in from any of the six remote lines and override the program on the control-room speaker. The



Courtesy RCA

Fig. 18-2. Simplified block diagram of a control-room installation.

"Record" position of this switch furnishes a signal source for an external recording amplifier or other destination.

Control-room equipment and layout vary over a considerable range and variety from composite setups through regular commercial consoles and custom-built equipment. Fig. 18-3 illustrates the type of studio control consoles at WHK in Cleveland.

At WHK, each studio has its own control room. The consoles for all the studios are identical and were built by the WHK engineering staff. This was not done for economic reasons, but because none of the commercially available consoles were suitable for the particular needs at hand. Each console is set up to handle six microphones normally, with provision to patch in as many more as needed. Each input has a preamplifier and mixing is done at high level. All mixers in studio control and master control at WHK are the vertical type, which may be a surprise to some readers.

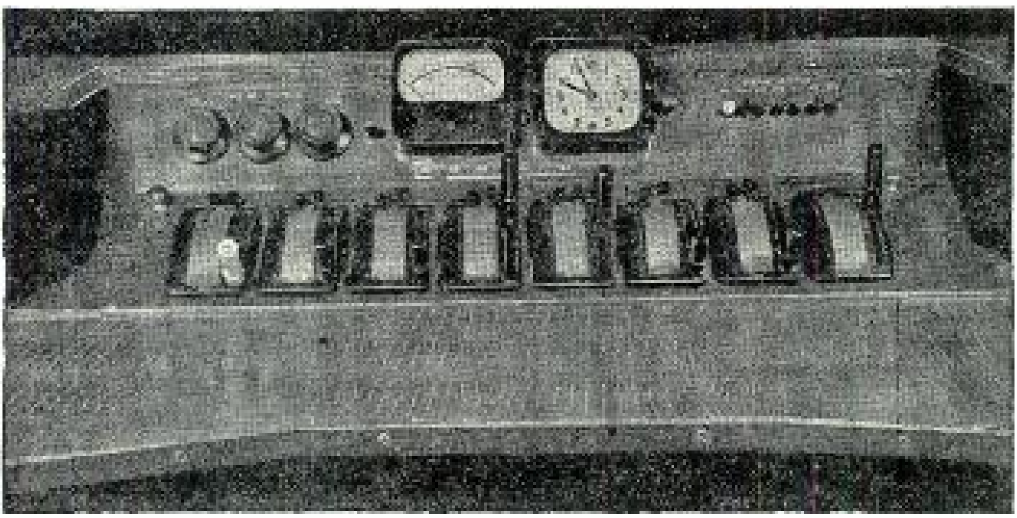


Fig. 18-3. The handles of the faders on the studio consoles at Station WHK are vertical, making them easier to handle than rotary faders.

Vertical faders have several advantages wherever space is no consideration. More vertical faders can be handled competently with one hand than rotary faders. The amount which a vertical fader is opened is instantly and graphically apparent; that is, the eye can tell whether it is ½, ⅔, or ¾. Regardless of how a rotary fader is marked, it takes some concentration to determine how far open it is, provided the knob has not turned on the shaft. Every man who ever worked at WHK and then worked somewhere else, has agreed that the vertical type is much easier to use, especially on large programs.

In addition to the microphone inputs there is a high level input into which master control can patch any desired program source. This allows smooth handling of multisource programs. As a matter of fact, any fader may be used as a high level input by patching the program in after the preamplifier. It is standard practice at WHK to have every piece of equipment come out on jacks. All equipment which is normally used together is connected through normal through jacks. Then there is a master fader which controls the console output. The fader system is a complete unit hooked up between the preamplifiers and the line amplifier, and has some interesting possibilities in case of trouble. Fig. 18-4 illustrates the basic mixing circuit.

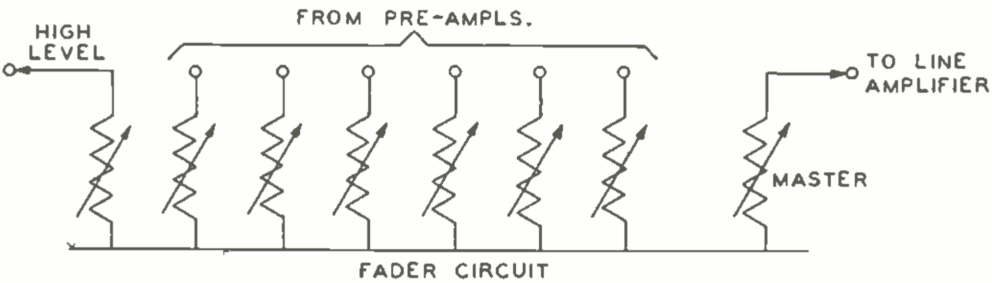
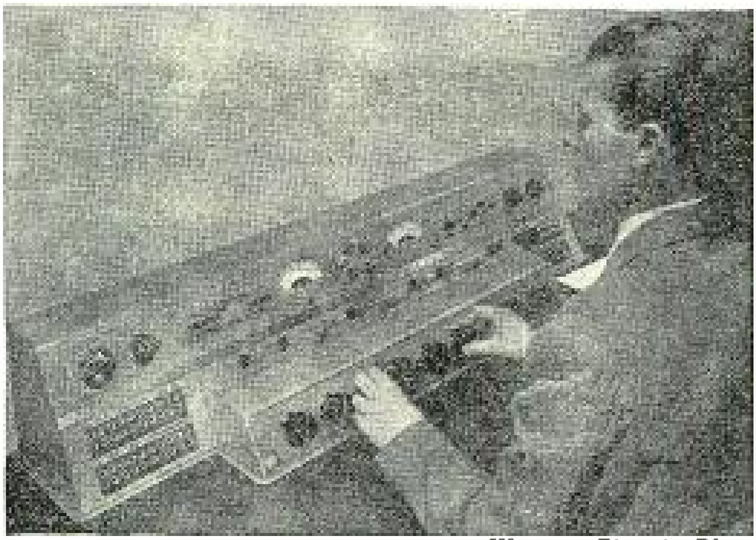


Fig. 18-4. The basic mixing circuit of the fader system used in the console shown on the opposite page.

All faders whether used for high level, microphone, or master, are exactly alike, so that anyone can be used for any purpose. When the top of the fader is used as an input, it deposits the program onto a bus, minus the vu loss of the fader setting. By using the top of the fader for an output, the program on the bus is fed to any desired place minus the vu loss of the fader setting. The faders are all 600 ohms in and 600 ohms out. If the master fader in the diagram of Fig. 18-4 went out of order, any of the microphone faders not in use, or the high level mixer, could be patched to the line amplifier and would become the new master fader.

There are two line amplifiers in each console, one of which is wired through normal jacks and one which may be patched to replace the regular. There are two power supplies, either one of which can be selected by a change-over switch. There is also a monitor amplifier, a p-a amplifier with separate gain control, and a communications amplifier for talking to studio or master control. The microphone and speaker of the communication system are mounted flush in the surface of the console. All amplifiers are vertically mounted in the console with doors which expose the tubes on one side or the bottom of the amplifier on the other. This makes for easy servicing. Characteristics of all equipment except the communications portion, is plus or minus 0.5 db from 30 to 15,000 cycles. For the convenience of the operator there are six monitor buttons by means of which he can select his own console output, master control output, final station monitor, network,



Western Electric Photo

Fig. 18-5. This type of control-room console is more usual than that illustrated in Fig. 18-3.

and two spares into which anything else may be patched. None of these buttons affect the on-the-air program. There is also a pilot light system which indicates to the studio operator every place his program is going, local station, network, audition room, executive's office, etc. Fig. 18-5 illustrates another type of control-room console.

BROADCAST MICROPHONES

The microphone, first gateway through which all sounds are passed on to the "mixing" network of the control console, is the most important instrument under the direct supervision of the control operator or producer.

Much depends on the characteristics and operational interpretation of this first link. First, it must have a wide frequency range. High-fidelity amplifiers would be useless without high-fidelity microphones. Second, it must have very low internal noise level for the wide dynamic range necessary to please exacting listeners, and to meet engineering standards of broadcast quality transmitters and receivers.

Next, it must possess a definite and dependable response pattern in relation to angle of incidence of the sound waves so that pickup areas may be properly defined. In broadcasting, we are concerned with wanted and unwanted sounds, and all shades in between. Aurally correct blending of musical and vocal sounds involves correct usage of the microphone characteristics as much as the proper manipulation of the mixing controls on the control panel.

Since, in nearly all installations of broadcast studios it is necessary for the microphone to be placed a considerable distance from the preamplifier, a low output impedance is desirable. This is important since the microphone cable possesses distributed capacitance which would seriously affect the higher frequencies if a high impedance were used. The most common preamplifier input impedances for broadcast use are 30, 50, and 250 ohms. All microphones, regardless of type, are of the same impedance at any given broadcast station. A ribbon microphone, condenser, dynamic, or combination type may be plugged into the microphone inlet without adjustment of impedance values. Output level is very low in most high-quality microphones, ranging from about minus 55 db to minus 90 db where the reference level is one milliwatt for a sound pressure of 10 dynes per square centimeter. Frequency response is comparatively good over a range of 30 to 15,000 cycles. Internal noise level is well under 50 db below no signal conditions.

Microphone Fundamentals

Fig. 18-6 shows the primary function of a "pressure" type microphone such as the dynamic, condenser, or crystal type. Sound waves

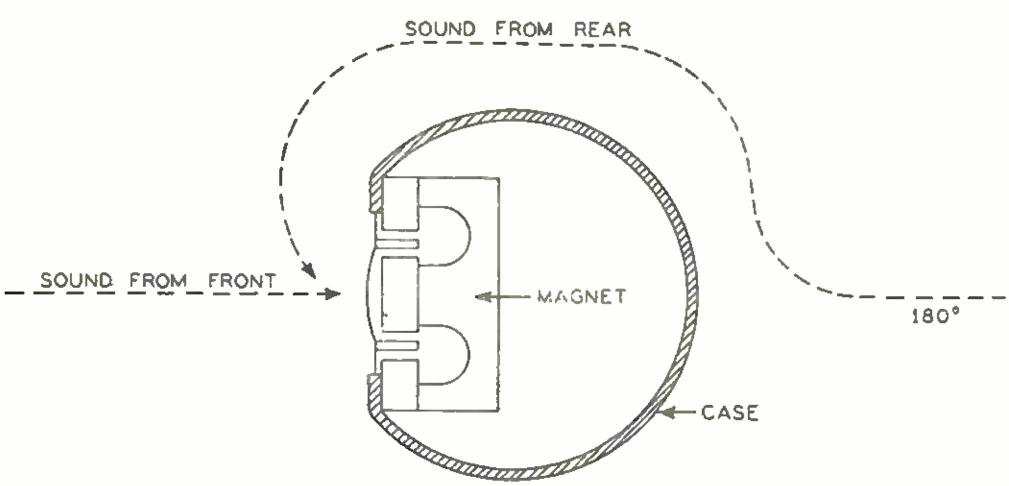


Fig. 18-6. The diaphragm of the "pressure" type microphone always moves in the same direction whether the sound comes from the front or rear.

of alternate condensations and rarefactions of air entering the microphone cause the pressure variations of the diaphragm to actuate the moving element between the magnetic pole pieces, which in turn generates a small electric current in accordance with the sound waves. The diaphragm always moves in the same direction regardless of the initial direction of the sound.

Fig. 18-7 illustrates the function of the "ribbon" or "velocity" microphone. This instrument consists essentially of a thin metallic ribbon

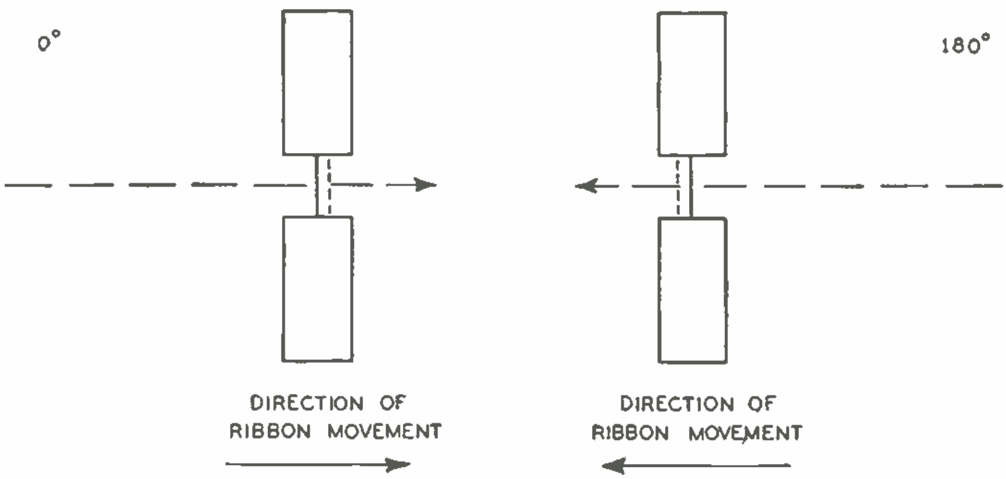


Fig. 18-7. Sound coming from the front or rear (0° or 180°) of the "velocity" microphone actuates the diaphragm, but sound coming from the side (90°) does not cause the diaphragm to vibrate.

suspended between two magnetic pole pieces without a diaphragm or associated cavity. As the sound waves strike the ribbon from one direction, the element is caused to move since a pressure difference exists in any sound field between any two given points. Since this differential pressure exists between the front and back of the ribbon, the ribbon will naturally move in the direction of diminishing pressure. This rate of change of pressure with distance is called "pressure gradient" and is the principle upon which the ribbon microphone operates. As observed from Fig. 18-7, sound approaching from the opposite direction causes the element to move in the opposite direction according to the pressure gradient principle. The ribbon can move only along the axis perpendicular to its surface, and sound waves entering from the side 90° from either "face" of the microphone cause an equal pressure on both sides, hence zero response. Thus this microphone gives the conventional "figure eight" response pattern, in comparison

Porcelain sockets and stand-off insulators crack due to heat expansion if they are excessively tightened. Do not overtighten them. Care should be taken when tightening the tube caps of high-voltage tubes. Use the proper screw driver or tool; if the tool should slip it may fall against the glass envelope of the tube and ruin a perfect tube.

(2) Tighten all tube connections, terminals, sockets, and stand-off insulators which were found loose during the inspection procedure. When tightening tube sockets having stand-off insulators, determine before tightening whether the fiber washers between the socket and the stand-off insulators are intact. If these fiber spacers are cracked or missing, replace them before tightening the tube socket. Tightening the socket without these spacer washers breaks or cracks the porcelain-tube socket.

Clean (C). In the performance of this item, clean only where necessary. Do not remove tubes for cleaning purposes unless it is impossible to clean them in their original positions. If the tube must be removed, exercise care in doing so. Do not attempt to clean the envelopes if they are located in an out-of-the-way place; in this case remove them for cleaning. When tubes are removed for cleaning, replace them immediately afterward. Do not leave them where they may be broken.

(1) Clean the entire tube assemblies with a clean dry cloth if the glass envelope is excessively dirty. Wipe the glass envelope with a damp cloth moistened in water. Polish after cleaning with a clean dry cloth. Do not wipe metal tubes with a cloth moistened in water, as this causes the metal body of the tube to rust. Use a cleaning agent if the tube is excessively dirty because of oil deposits. Generally, metal tubes with oil deposits on their envelopes can be cleaned successfully by polishing dry with a clean dry cloth. The oil film remaining on the metal body of the tube prevents the tube from rusting. To remove oiliness, corrosion, or rust from tube envelopes, moisten a clean cloth with cleaning agent and clean the area affected until it is clean. Wipe dry with a clean dry cloth.

(2) Clean the grid and plate caps, if necessary, with a piece of #0000 sandpaper, or crocus cloth. The paper should be wrapped around the cap and gently run along the surface. Excessive pressure is not needed; neither is it necessary to grip the cap tightly. Clean the caps completely before replacing them on the tube terminals if corrosion is noted on the grid or plate caps.

(3) When the tube sockets are cleaned and the contacts are acces-

sible, fine sandpaper should be used if corrosion is present on the contacts. Clean the contacts thoroughly after sandpapering. Clean all areas surrounding tube sockets with a brush and a clean dry cloth; this prevents dust and dirt from being blown back on the tube envelopes when the unit is put back into operation.

Adjust (A). When performing this operation, care must be taken to arrange all leads and terminals to correspond as closely as possible with their original positions.

(1) Adjust all leads and tube connections. Check to determine if the leads are resting on the glass envelope of the high-voltage tubes; if they are, redress the leads so that proper spacing is obtained. Examine all leads connecting to the tube caps. These should not be so tight that they barely reach the caps of the tubes. If this condition is found, redress these leads so that enough "play" is obtained. Adjust all grid clamps so that the proper tension is obtained. To increase the tension of tube clamps, close the spring clamps slightly with a pair of long-nose pliers until the proper tension is obtained. Do not flatten the clamps.

(2) Tube sockets used for transmitting-type tubes should be adjusted if the tube is found loose in its mounting. The terminals of these sockets are spring-tensioned so that they may be adjusted to increase the pressure against the tube pins. To adjust these contacts, simply bend them toward the center on the socket until the correct tension is obtained. Do not apply too much pressure to the spring contacts; they may be broken from their mountings in the porcelain socket.

(3) Any difficulty in removing or inserting metal tubes can be remedied easily. Remove the metal tube and examine the tube pins to determine if solder or corrosion has accumulated on the pins. Remove solder deposits with a penknife; then polish the pins with fine sandpaper. Do not use a soldering iron to remove solder deposits; this makes them worse, as the solder is built up on the pins rather than removed. To remove corrosion, use fine sandpaper, but never use it unless it is absolutely necessary. Saturate a small piece of cleaning cloth with light lubricating oil or petroleum jelly, and wipe the tube pins. Remove the excess oil from the pins by wiping them almost dry with a clean dry cloth. If these procedures are followed, no difficulty will be experienced in removing or reinserting the metal tube into its socket.

Caution: Do not force metal tubes into their sockets. Do not pry or "wiggle" them loose, since this damages the prongs of the socket and results in intermittent operation of the unit in which they are located.

Capacitors

High-Voltage Capacitors. High-voltage capacitors, because of their high operating potentials, must be kept clean at all times to prevent losses and arcing. Dirt, oil deposits, or any other foreign matter must not be allowed to accumulate on the high-voltage terminals of these capacitors. All leads and terminal connections must be inspected periodically for signs of looseness and corrosion, and the porcelain insulators inspected for cracks or breaks.

Low-Voltage Capacitors, Oil-Filled. Low-voltage oil-filled capacitors require the same care as those of the high-voltage type, although the frequency of the maintenance operation is not so critical. The terminals and connections of these capacitors should be given the same careful inspection as those of the high-voltage types. The leads of these capacitors are not as rugged as those used on the high-voltage capacitors and should be inspected more closely for poorly soldered connections.

Tubular Capacitors. These capacitors are of the low-voltage paper type and are generally used in low-voltage circuits for coupling and bypassing. They should be inspected and cleaned whenever the chassis in which they are located is removed for maintenance. The only maintenance requirement for these capacitors is inspection of the tubular body of the capacitor for bulging, excessive swelling of the capacitors, and for signs of wax leakage. The terminal leads (pigtail type) of the capacitors are inspected for firmness of contact at their respective points of connection. Never use a cloth to clean this type of capacitor, as damage to the surrounding circuits may result. These capacitors are easily cleaned with a small, soft brush. All dirt and dust are brushed from the body of the capacitor and the surrounding area.

Mica Capacitors. Mica capacitors require very little maintenance other than being kept free from dust and oil. Two types of mica capacitors are generally used: the high-voltage and the low-voltage type. The low-voltage types are inspected whenever the chassis of the unit in which they are located is being maintained. The capacitors are inspected for cracked body conditions caused by excessive heat, while their leads (pigtail type) are inspected for firmness of contact at their respective points of connection. The high-voltage types, however, require terminals because of their high operating potentials. These terminals must be inspected for tightness and corrosion, firmness of mounting, and body conditions. The body of these capacitors is of a ceramic material and care must be exercised when tightening the mountings of these capacitors. The bodies of the capacitors are easily kept clean with a dry clean cloth. For satisfactory operation the terminals must be free from dirt and corrosion at all times. Take care when tightening the terminals of these capacitors, as excessive pressure damages or cracks the ceramic case where the terminals are coupled to the body of the capacitors.

Trimmer Capacitors. In very damp climates, trimmer capacitors must be inspected often. Dampness, if allowed to accumulate on the plates of the capacitors, results in erratic operation of the unit in which the capacitors are used. In certain cases where high voltage is used, serious damage to the capacitors results. A minute amount of moisture or a tiny bead of water is all that is necessary to short-circuit the plates of the capacitor and cause abnormal operation. When such conditions are encountered, the capacitor must be thoroughly dried by the heat process which requires the use of a small portable heater. A cleaning cloth used to dry the plates of the capacitors may throw the plates out of alignment when the cloth is inserted between them. In extreme cases where the plates of the capacitors are very closely spaced, use a magnifying glass to locate the exact position of the moisture beads existing between the plates. Due to the sheen of the capacitor plates, very minute particles of moisture cannot always be detected by the naked eye.

Maintenance Procedures for Capacitors.

Caution: To avoid severe electrical shock in case of bleeder failures, *discharge* all high-voltage capacitors before maintenance.

Feel (F). Feel the terminals of the high-voltage filter capacitors. These should be fairly cool. Excessive heat probably indicates losses due to loose, dirty, or corroded terminal connections. Feel the sides of oil-filled and electrolytic capacitors. These should be cool or slightly warm. If they are very warm or hot, the condition indicates excessive internal leakage. Capacitors in this condition are subject to failure at any time and should be reported for immediate replacement.

Inspect (I). Inspect the general condition of all capacitors regardless of type. Inspect for broken, frayed, or loose terminals, leads, and connections. Inspect the condition of the terminals of the high-voltage capacitors. Check these for dirt, corrosion, and looseness. Inspect the body of the capacitors for excessive signs of bulging and oil leakage.

Inspect the plates of the tuning capacitors for dirt and corrosion. Check all capacitor shafts, bushings, bearings, and couplings for looseness or binding.

Tighten (T). Tighten all loose terminals, connections, and terminal leads on all types of capacitors. Tighten all capacitor mountings and stand-off insulators. Tighten all loose shaft couplings and bushings.

Clean (C). Special attention should be given to all high-voltage capacitors to insure that they are not only kept clean, but are free from moisture. Thoroughly clean the insulators, terminals, and leads of high-voltage capacitors. When extremely damp, due to high humidity, these capacitors frequently have to be wiped dry with a clean, absorbent cloth to prevent arc-overs and breakdown of insulation. Remove terminals that appear to be either corroded or dirty; also remove those causing power losses due to high-resistance connections. Clean them with a crocus cloth which is either dry or moistened with cleaning fluid. Polish the terminals dry after cleaning with a clean, dry cloth. Replace all connections after cleaning, making certain that good electrical contact is obtained. The low-voltage capacitors require little attention. However, all insulated bushings and supports should be kept clean and free from foreign matter.

Adjust (A). Adjust all leads if necessary. This requires the redressing of leads which may have been dislocated during the maintenance procedure. If capacitor leads are stretched too tightly, redress or replace them until the correct lead placement is obtained.

Resistors

Resistors may be divided for maintenance purposes into two groups: the first group consists of those resistors easily detachable and known as *ferrule-type resistors;* the second group includes those whose terminals are soldered and are known as *pigtail-type resistors.*

a. Ferrule-Type Resistors.

Caution: Do not touch power resistors immediately after the power has been shut off. They are usually hot, and severe burns may result.

Feel (F). The springiness of ferrule clips may be ascertained when removing the ferrule-type resistor. Insufficient *pull* at the clip may be an indication of a loose connection and poor electrical contact.

Inspect (I). It is important to inspect all types of resistors for blistering or discoloration, for these are indications of overheating. Inspect the leads, clips, and metalized ends of the resistors and adjacent connections for corrosion, dirt, dust, looseness, and broken strands in the connecting wires; also inspect the firmness of mounting.

Tighten (T). Tighten all resistor mountings and connections found loose. If the tension at the end clips has decreased, it is common practice to press the clip ends together by hand or with a pair of pliers. The hand method is preferred because the pliers may bend the clip or damage the contact surface.

Clean (C). Dirty or corroded connections of ferrule-type resistors can be cleaned by using a brush or cloth dipped in cleaning fluid. If the condition persists, use crocus cloth moistened with cleaning fluid. It may be necessary to sandpaper the resistors lightly with fine grade sandpaper, such as #0000. Always wipe clean with a dry cloth before replacing them. Vitreous resistors connected across high voltage should be kept clean at all times to prevent leakage or flashovers between terminals. They should be wiped clean with a dry cloth or a cloth moistened with cleaning fluid. If cleaning fluid is used, the resistors must be polished with a dry clean cloth.

Pigtail-Type Resistors. Maintenance of pigtail-type resistors is limited to an inspection of soldered connections. Such connections may break if the soldering is faulty or if the resistors are located in a place subject to vibration. The recommended practice is to slide a small insulated stick lightly over the connections and to inspect them visually for solidity. If connections are noticeably weak or loose, they should be re-soldered immediately. Discolored or chipped resistors indicate possible overloads. Although replacement is recommended, resistors in this condition have been known to last indefinitely. The pigtail-type connections should be dusted with a brush or with an air blower if available.

Fuses

A fuse consists of a strip of fusible metal inserted in an electric circuit. When the current increases beyond a safe value, the metal melts, thus interrupting the current. Fuses vary in size and rating depending upon the circuits at which they are used. Some are designed to carry currents in milliamperes. Being very rapid in action, they protect the equipment from overloads and damage. Two types of fuses are used: renewable and nonrenewable. The first type is designed so that the fuse link, or element contained within the fuse cartridge, may be removed and replaced when blown. The second type, however, is constructed so that the fuse element is permanently sealed within the fuse housing. When a fuse blows, an attempt must be made to determine the reason for its failure, and to make corrections, if possible, before a new fuse is installed; then the complete fuse assembly must be replaced.

Renewable Type. The renewable type fuse assembly consists of a housing or cartridge of insulating material with a threaded metal cap (ferrule) at each end. The fuse element or link, as a precaution against damage, is placed inside the cartridge or housing and it is held in position by the two end caps, or ferrules. When a fuse is placed in service, the two ends of the fuse cartridge are slid into spring contacts mounted on the fuse block. This places the fuse in the circuit to be protected.

Nonrenewable Type. When nonrenewable fuses are blown, they must be discarded. Certain types of nonrenewable fuses are removed by unscrewing and withdrawing the cap screws that hold them in place. When removed, the fuse and cap screw are separated by pulling apart. The glass fuses are easily removed for inspection. Care must be taken to see that the fuse end and holding clips are kept clean and tight . If they are not, overheating will result and make replacement necessary.

Inspect (I). Inspect the fuse caps for evidence of overheating and corrosion. Inspect the fuse clips for dirt, loose connections, and proper tension.

Tighten (T). Tighten the end caps, the fuse clips, and connections to the clips on replaceable fuses if they are found to be loose. The tension of the fuse clips may be increased by pressing the sides closer together. Fuse caps should be hand-tightened only. Excessive tightening results in difficulty in removing them when required.

Clean (C). Clean all fuse ends and fuse clips with fine sandpaper when needed; wipe with a clean cloth after cleaning. If it becomes necessary to use a file to remove deep pits in the clips, fuse ends, or contacts, always finish up with fine sandpaper in order to leave a smooth contact surface. As a final step, wipe the surface clean with a clean dry cloth.

Bushings and Insulators

Bushings and insulators are extremely important elements in electric circuits, especially when located in high-voltage circuits where insulation breakdown is most common. Most of the high-voltage insulators are constructed of ceramic material with highly glazed surfaces.

Caution: Exercise extreme care when working near these insulators. They are easily chipped or broken.

Inspect (I). Thoroughly inspect all high-voltage insulators and bushings for moisture, dust, and other accumulated foreign matter. Unless they are both clean and dry, leakage or arc-overs will occur and damage them permanently. Check the chipped surfaces, hair line cracks, carbonized arc-over paths, and other surface defects that may make the insulator unserviceable. Insulators in this condition should be reported to the person in charge for replacement.

Tighten (T). Feed-through bushings, stand-off and other insulators should be tightened if found to have loose mountings or supports. Tighten these insulators with care because gaskets absorb only a small amount of pressure before breaking.

Clean (C). Cleaning operations are similar to those outlined for tubes. Use a clean cloth (dampened with cleaning fluid if necessary) to remove dust, dirt, or other foreign matter. Always polish with a dry, absorbent cloth after cleaning.

Relays

The various types of relays may be classified as follows: overload relays, time delay relays, and magnetic contactors. Relays require a certain amount of preventive maintenance, which must never be performed except when absolutely necessary. Certain types will be found to be completely encased in dustproof and moistureproof cases. These require little maintenance other than a periodic inspection.

Maintenance of relays requires that they be inspected periodically and preventive maintenance measures performed if necessary. The inspection procedure requires that the terminals be inspected for looseness, dirt, and corrosion. Contacts may have become loosened because of the jarring of the equipment during shipment. The contacts may become dirty or corroded due to climatic conditions where the equipment is being operated. Relay contacts must never be sandpapered or filed unless the operation is absolutely necessary for the normal operation of the relay unit. A relay is considered normal if:

(1) The relay assembly is free from dirt, dust, and other foreign matter.
(2) The contacts are not burned, pitted, or corroded.
(3) The contacts are properly lined up and correctly spaced.
(4) The contact springs are in good condition.

(5) The moving parts travel freely and function in a satisfactory manner. The solenoids of plunger type relays must be free from obstructions.
(6) The connections to the relay are tight.
(7) The wire insulation is not frayed or torn.
(8) The relay assembly is securely mounted.
(9) The coil shows no sign of overheating.

A relay is considered abnormal if it fails to meet any of the above-mentioned requirements. The following are the maintenance procedures used in the maintenance of relay units.

Inspect (I). Inspect the relays, to determine abnormal conditions using the check list given above. If the contacts are not readily accessible, they may be examined with the aid of a flashlight and mirror. Many of the relays can be inspected and cleaned without being removed from their mountings or without being taken apart. Mechanical action of the relays should be checked to make certain that the moving and stationary contacts come together in a positive manner and that they are directly in line with each other. The armature or plunger mechanism should move freely without binding or dragging. Care should be taken during inspection not to damage or misalign the relay mechanism. Relays that require the removal of the cover for complete inspection may be found enclosed in glass, Bakelite, or metal cases. Relays must never be taken apart unless it is absolutely necessary. If they must be taken apart for maintenance purposes, care should be exercised in doing so. When disassembling relays, tag all leads as they are being removed. This insures that the proper leads are returned to their proper terminals after the maintenance procedure is completed.

Tighten (T). Tighten all loose connections and mounting screws found loose, but do not apply enough force to damage the screw or to break the part which it holds. Do not start screws with their threads crossed. If a screw does not turn easily, remove it and start again. Relay coils can be tightened by inserting, if possible, a small wooden or paper wedge between the coil and the core of the relay. This prevents chatter of the relay. Tighten any and all loose connections. Tighten also the mounting of the relay assembly, if it is found loose. When replacing glass or Bakelite covers over relay cases, take care not to overtighten the screw cap holding the glass or Bakelite cover over the relay assembly.

Clean (C). Clean the exterior of the relay with a dry cloth, if it is very dirty; clean with a cloth or brush dipped in cleaning fluid; then wipe the surface with a dry cloth. If loose connections are found, they should be inspected. If inspection reveals that the connections are either dirty or corroded, they should be removed and cleaned before tightening.

The relay service aid is a narrow piece of folded cloth or canvas. It serves a twofold purpose: it is suitable for polishing a clean surface, and it is used as a follow-up to a crocus cloth. It is also intended to remove grains of pumice which came off the crocus cloth and adhere to the contact surface. The cloth is used as shown in Fig. 17-2.

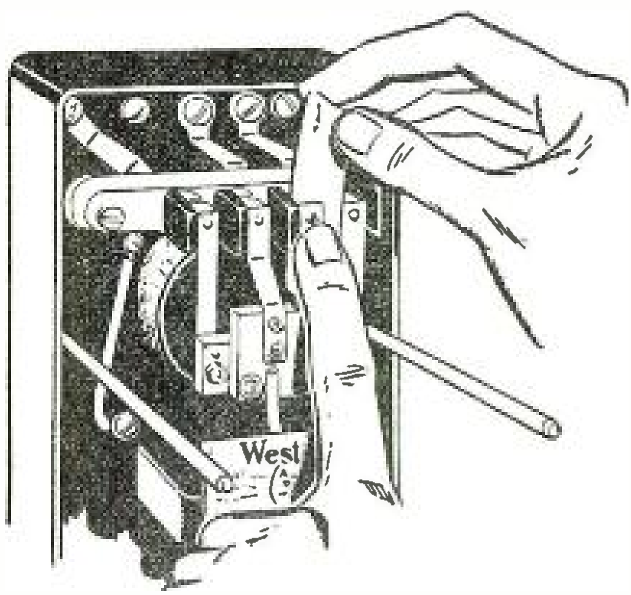


Fig. 17-2. Relay contact surfaces are polished by a narrow strip of cloth or canvas as shown in the sketch.

Cleaning Relay Contacts. The following information should be carefully studied. It instructs how relay contacts of various types should be cleaned.

Hard contacts. Hard alloy contacts are cleaned by drawing a strip of clean wrapping paper between them while holding them together. It may be necessary in some cases to moisten the paper with cleaning fluid. Corroded, burned, or pitted contacts must be cleaned with the crocus cloth strip or the burnishing tool as shown in Fig. 17-3.

Solid silver contacts. Dirty contacts. Dirty solid silver contacts are easily cleaned with a brush dipped in cleaning fluid. After being cleaned, the contacts are polished with a clean dry cloth.

Note: The brown discoloration that is found on silver and silver-plated relay contacts is silver oxide and is a good conductor. It should be left alone unless the contacts must be cleaned for some other reason. It may be removed at any time with a cloth moistened in cleaning fluid.

Corroded contacts: Dress the contacts first with crocus cloth, using either the stick or the strip of crocus material. When all of the corrosion has been removed, wipe with a clean cloth moistened in cleaning fluid and polish with a piece of folded cloth. Make certain that the shape of the contacts has not been altered from the original.

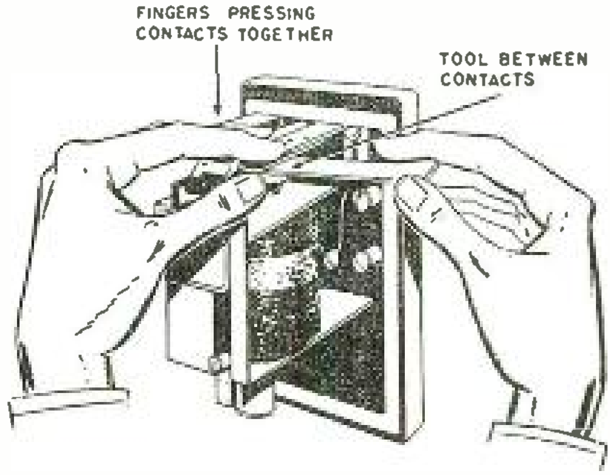


Fig. 17-3. Hard alloy contacts of a relay are cleaned by pulling a strip of clean wrapping paper between them while pressing the contacts together.

Burned or pitted contacts: Resurface the contacts, if necessary, with #0000 sandpaper, making certain that the original shape of the contacts is not changed. Next, smooth the surface of the contacts with crocus cloth until a high polish has been obtained. Wipe thoroughly with a clean cloth to remove the abrasive remaining on the contacts. When contacts are very badly burned or pitted and replacement is not available, the small fine-cut file and #0000 sandpaper should be used in keeping with instructions given later.

Silver-plated contacts. Dirty contacts: Dirty silver-plated contacts are cleaned with a cloth or brush dipped in cleaning fluid. After being cleaned, the contacts are polished with a dry cloth.

Corroded contacts: Dress first with crocus cloth, using either the stick or strip of crocus material. The work must be done very carefully not to remove an excessive amount of silver plating. When all of the corrosion has been removed, polish with a clean dry cloth. Make certain that the shape of the contacts has not been altered.

Burned or pitted contacts: Dress the contacts with crocus cloth until the burned or pitted spots are removed. This may require an appreciable amount of time and energy, but it is preferable to using a file or sandpaper. If it is found that the crocus cloth does not remove the burns or the pits, use the sandpaper tool very carefully. When sandpaper is used, it must be followed with crocus cloth to polish the contacts, and then wiped thoroughly with a cloth moistened in cleaning fluid. The contacts are then polished with a clean dry cloth.

Warning: Never use highly abrasive materials, such as emery cloth, coarse sandpaper, or carborundum paper for servicing relay contacts, as damage to the contacts will result.

Adjust (A). Adjust relay contacts after cleaning if necessary. The contacts should close properly when the plunger is hand operated. Adjust the relay springs if necessary. Do not tamper with the relay springs unless it is absolutely necessary. These springs are factory adjusted and maintain a certain given tension and rarely get out of adjustment. If the spring tension must be changed, exercise care when doing so. The adjustment of the current control relays is accomplished by setting calibrated knobs to the desired setting, or by turning a knurled adjustment sleeve which has a calibrated scale mounted adjacent to it. The adjustments should not be changed from their original factory setting except in cases of emergency. Overload relays must never be adjusted unless the person in charge has been notified, and has sanctioned the adjustment.

Shapes of Relay Contacts. Relay contacts are of varied shapes, as shown in Fig. 17-4 depending upon their size and application. In some

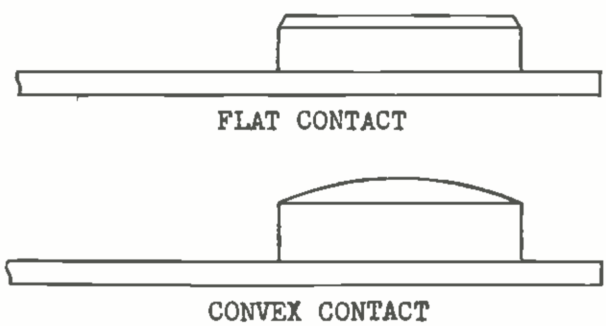


Fig. 17-4. The original shape of the contacts must be retained. This shape may be either flat or convex, as shown at the left.

instances, both contacts are flat; in others, one contact is convex while its mate is flat. The original shape of a contact must be retained during cleaning. If burning or pitting has distorted the contact so that it must be reshaped, the original shape must be restored. It is essential that the maintenance personnel familiarize themselves with all details of the relays by examining them while the relays are in good condition. In this way, they will be better prepared to do their work well.

Relay Servicing Tools and Their Use

To service the relay contacts, several types of tools are needed. Each of these has a special function, as described below.

The Burnishing Tool. This tool is used on relays which have extremely hard contacts made of palladium or elkonium. This tool is not a file. A contact should not be burnished unless it is found to be pitted or oxidized, and then not more than is necessary to restore a clean smooth surface. The original shape of the contact must be retained.

Small Fine-Cut File. This file is to be used only on the larger contacts when they have become very badly burned or pitted, and a replacement is not available. This tool is not to be used on silver-plated contacts, or on the contacts of the telephone-type relays. The file should not be used more than is necessary to remove the pit. The original shape of the contact must be preserved. After filing, #0000 sandpaper should be applied to the contact, and followed with crocus cloth to obtain a smooth finish on the contact surface. A clean dry cloth serves for final polishing.

The #0000 Sandpaper Stick. This tool is made in the same way as the crocus-cloth stick, except that sandpaper is used instead of crocus cloth. The use of sandpaper is limited, as is the use of the fine-cut file, to the treatment of badly burned or pitted contacts on the larger relays. Sandpaper is not used on silver-plated contacts, except under extreme circumstances, and when used should be followed with crocus cloth. All contacts should be polished after sanding, with a clean dry cloth.

Crocus Cloth. This maintenance aid is available in two forms—as a tool and as a strip of material. It serves a twofold purpose: it may be used to remove corrosion from all relay contacts, or it may be applied to the contacts following the use of the fine-cut file and #0000 sandpaper. Neither the file nor sandpaper leaves a finish smooth enough for proper relay operations. Use crocus cloth to polish the surface of the contact. The choice between the stick and the piece of cloth depends upon accessibility. If the location of the relay and the position of the contacts permit the use of the crocus-cloth stick, it should be used; otherwise, the strip of crocus cloth must serve. The crocus cloth and tool are used as illustrated in Figs. 17-2 and 17-3. In both cases the maintenance aid is inserted between the contacts and is drawn through them while the contacts are pressed together with the fingers.

Switches

For the purpose of maintenance, switches may be classified into two general groups: those whose contacts are readily accessible, and those whose contacts are completely encased. The basic maintenance operations of "Inspection," "Cleaning," "Adjusting," and "Lubrication" are applicable only to the first group. Because of the enclosed construction of the second group, no maintenance can be applied. The work is limited to a mechanical test of their operations.

Accessible Contact Switches. This group consists of knifeblade switches, start-stop push-button switches, and high-voltage shorting bars. With the exception of the shorting bars, all of these switches consist of blades which are mechanically inserted into spring contacts.

Inspect (I). Inspect all the terminal connections of each individual switch for tightness and cleanliness. The mounting of the switch should be checked for firmness. Operate the mechanism of the switch and see if the parts move freely. Observe the stationary spring contacts to determine whether they have lost tension and whether they are making good electrical contact.

Tighten (T). All loose mountings and connections should be tightened properly. If inspection shows that the fixed contacts have lost tension, tighten them with the fingers or pliers. Tighten every connection or terminal found loose.

Clean (C). If inspection shows that any terminal, connection, or section of the switch is dry, dusty, corroded, or pitted, clean the part by using a dry clean cloth. If the condition is more serious, moisten the cloth with cleaning fluid and rub vigorously. Surfaces which have been touched with the bare hands must be thoroughly cleaned with a cloth moistened in cleaning fluid, and then polished with a clean cloth. The points of contact with the moving blade are naturally those which most often show signs of wear. Examine these points very carefully to insure that both sides of each blade, as well as the contact surfaces of the clips, are spotlessly clean at all times. Crocus cloth moistened with cleaning fluid should correct this condition; however, if it is not corrected, #0000 or #000 sandpaper may be used. Always polish clean after the sandpapering operation.

Adjust (A). Some of the switches have a tendency to fall out of alignment because of loosening of the pivot. In most cases, tightening the screw on the axis of motion corrects this condition.

Lubricate (L). If binding is noted during inspection of the operation of the switch, apply a drop of instrument oil with a toothpick to the point of motion or rotation. Do not allow oil to run into the electrical contacts, as a film of oil may cause serious damage or a poor contact. Lubrication of switches is not recommended unless serious binding is noticed.

Nonaccessible Contact Switches. Under this heading are included all the remaining switches not discussed in the previous paragraph. Interlock switches, toggle switches, meter protective push buttons, and selector switches have been designed so that it is impossible to get at the contact without breaking the switch assemblies. The only maintenance possible is to check the operation of the switch assemblies and, if something abnormal is detected, to notify the person in charge immediately so that a spare may be obtained and a replacement made as soon as possible. Do not lubricate any of these switches under any circumstances.

Generators and Motors

Certain preventive maintenance procedures must be applied to these components if proper functioning and dependable performance are to be obtained. There are three principal cases that contribute to faulty operation of this type of equipment: accumulation of dirt, dust, or other foreign matter on the windings and moving parts of the equipment; lack of sufficient lubrication on bearings and other moving parts; and improper adjustments or damaged parts. Given proper maintenance care, motors and generators give long and efficient service. In addition to the techniques given in the following paragraphs, additional maintenance instructions covering certain motors or generators will be found in various items of the manufacturer's instruction books. Unless specifically mentioned, the maintenance techniques that follow apply to the motors and generators used in the transmitter.

Feel (F). The bearing and the housings should be tested by feeling them to determine overheated conditions. An accepted test, except in very hot climates, is to hold the bare hand in contact with the bearing or housing for a period of at least 5 seconds. If the temperature can be tolerated this length of time, the bearing temperature may be considered normal. Overheating may indicate lack of sufficient lubrication, a damaged bearing surface, or, in rare situations, an excessive accumulation of dirt within the field windings.

Inspect (I). Each motor and generator exterior, and any other visible parts, must be inspected for dirt and signs of mechanical looseness or defects. Wherever wires are exposed, see that all connections are tight and in good condition and that the insulation is not frayed. Inspect the motor ends for excess oil and the mounting for loose bolts. Wherever possible and practicable, feel the pulleys, belts, and mechanical couplings to insure that the proper tension or tightness is present.

Tighten (T). Any mounting, connection, or part found loose must be properly tightened. If any internal part such as a commutator segment or an armature coil appears loose, notify the person in charge and repair the part immediately or replace it at the first opportunity. Operation under these conditions will cause considerable damage in a very short period of time.

Clean (C). Carefully wipe the exterior, base, and mountings of each motor and generator with an oiled cloth in order to leave a thin, protective film of oil on the surfaces. If available, use an air blower, or hand bellows to blow the dust and dirt out when inspection shows that the windings are dusty or dirty.

If inspection of the commutator and brushes shows that cleaning is necessary, the accepted cleaning practice is as follows: lift or remove the most accessible brush assembly and press a piece of canvas cloth folded to the exact width of the commutator against the commutator; then run the motor for about 1 minute, exerting the necessary pressure. If the condition still persists because the commutator has been burned or pitted, use a piece of fine sandpaper (#0000), preferably mounted on the commutator cleaning stick, and, exerting the necessary pressure, rotate the motor for approximately 1 minute. Stop the motor and wipe around the commutator bars with a clean cloth. It may be necessary to polish the commutator with a piece of canvas, as explained in the first procedure. Identical maintenance procedures apply to slip rings.

Transformers and Choke Coils

Some transformers are enclosed in metal housings, others are external, but in all cases they are impregnated with insulating compound. As a result, similar maintenance techniques are applicable to all of them.

Inspect (I). Carefully inspect each transformer and choke for general cleanliness, for tightness in connections of mounting brackets and rivets, for solid terminal connections, and for secure connecting lugs. The presence of dust, dirt, and moisture between terminals of the high-voltage transformers and chokes may cause flashovers. In general, overheating in wax- or tar-impregnated transformers or coils, is indicated by the presence of insulating compound on the outside or around the base of each transformer or coil. If this condition is encountered, immediately notify the person in charge.

Tighten (T). Properly tighten mounting lugs, terminals, and rivets found loose.

Clean (C). All metal-encased transformers can be cleaned easily by wiping the outer casings with a cloth moistened with cleaning fluid. Clean the casing and the immediate area surrounding the transformer base. Clean any connections that are dirty or corroded. This operation is especially important on high-voltage transformers and coils. It is very important that transformer terminals and bushings on all types of transformers be examined and kept clean at all times.

Variacs

Variacs, as a rule, are built sturdily and are protected so that very little maintenance other than regular inspection is required.

Inspect (I). Carefully inspect the exteriors of the variacs for signs of dirt and rust. Inspect the mounting of each variac to determine whether it is securely mounted. Inspect all connections for looseness, corrosion, and dirt. Check the slip rings for signs of corrosion or dirt.

Clean (C). The perforated casing of each variac as well as the area surrounding the base must be cleaned regularly. If the slip rings need cleaning, dismount the variac and clean with a cloth moistened in cleaning fluid and then polish with a clean dry cloth. If the dirty condition persists, use crocus cloth and rub vigorously. Again polish with a clean cloth. Reassemble the variac; then reinstall it, reconnecting all terminals carefully.

Lubricate (L). If the variac shaft shows signs of binding or if it squeaks, apply a few drops of household oil to the front and rear bearings. Rotate the control shaft back and forth several times to insure equal distribution of the lubricant in the front and rear bearings.

Rheostats and Potentiometers

Rheostats and potentiometers fall into two main groups for maintenance purposes; those which have the resistance winding and the sliding contact open and accessible, and those which, by construction, have their inner parts totally enclosed. In the latter group, very little maintenance can be performed, since opening and removing the metal case may damage the unit.

Inspect (I). The mechanical condition of each rheostat must be inspected regularly. The control knob should be tight on the shaft. Inspect the contact arm and resistor winding for cleanliness and good electrical contact. Check the rheostat assembly and mounting screws for firmness; the sliding arm for proper spring tension; and the insulating body of the rheostat for cracks, chipped places, and dirt.

Tighten (T). Tighten carefully any part of the rheostat or potentiometer assembly found loose.

Clean (C). The rheostat or potentiometer assembly is easily cleaned by using a soft brush and then polishing with a soft clean cloth. If additional cleaning is needed, or if the windings show signs of corrosion or grease, the brush may be dipped in cleaning fluid and brushed over the winding and contacts. With a clean cloth, remove the film that remains after the cleaning fluid has evaporated. If the contact point of the sliding arm is found burned or pitted, it is good practice to place a piece of folded crocus cloth between the contact and the winding and then to slide the arm a number of times over the crocus cloth. When cleaning the winding, do not exert excess pressure. or damage will result.

Adjust (A). If the tension of the sliding contact is insufficient, an adjustment can be made with the long-nose pliers. Slight bending of the rotating piece in the proper direction restores the original tension.

Lubricate (L). Apply lubrication only when necessary; that is, when binding or squeaking is noticed. One or two drops of instrument oil applied to the bearings with a toothpick is sufficient. Since the slightest flow of oil into the winding or the sliding-arm contact may cause serious damage, lubrication should be applied very carefully and only on the bearings. Wipe off all excess oil.

Terminal Boards and Connecting Panels

Little preventive maintenance is required on terminal boards and connecting panels.

Inspect (I). Carefully inspect terminal boards for cracks, breaks, dirt, loose connections, and loose mountings. Examine each connection for mechanical defects, dirt, corrosion, or breakage.

Tighten (T). All clean terminals, screws, lugs, and mounting bolts found loose should be tightened properly. Use the proper rods for the tightening procedure and do not overtighten or the assembly may become cracked or broken.

Clean (C). If a connection is corroded or rusty, it is necessary to disconnect it completely. Clean each part individually and thoroughly with cloth or crocus cloth moistened with cleaning fluid. All contact surfaces should be immaculate for good electrical contact. Replace and tighten the connection after it has been thoroughly cleaned.

Air Filters

Air filters are placed in blowers and ventilating ducts to remove dust from the air drawn into and circulated through the ventilating system. Some filters are impregnated with oil and some are filled with cut strands of glass to facilitate the filtering action. The following procedures cover their maintenance:

Inspect (I). The filter should be inspected for any large accumulation of dirt and for lack of oil. Note whether the filter is mounted correctly and whether the retaining clips are in place. Improperly assembled filter elements or wall frames, allow unfiltered air to leak around the edges and thus permit dust to enter the ventilating system.

Tighten (T). Tighten the retaining clips if they are found loose, and readjust the filter in its mounting.

Clean (C). The filters are easily accessible and may be taken out after removal of the cover plate. The general procedure is, as follows: mark the outside of the filter before removing it from the air duct. Before washing it, tap its edges against the wall or on the ground to remove as much dirt as possible. Wash the filter in gasoline, using a brush to remove dirt from the steel wool. After the filter has been washed, place it face down on two supports. Allow it to drain and dry thoroughly before lubricating.

Lubricate (L). Lubricate or recharge the filter element by dipping it in a bath of oil. In temperatures about 20 F., use SAE-10 oil. Allow the filter to drain thoroughly, intake side down, before it is put into use. While the filter is draining, keep the filter away from places where sand or dirt is being blown through the air. Always replace a filter with its intake side facing the incoming air flow.

Cabinets

The cabinets which house the various components of the set are generally constructed of sheet steel.

Inspect (I). The outside and inside of each cabinet must be inspected. Check the door hinges (if any), the ventilator mountings, the panel screws, and the zero-setting of the meters. Examine the pilot light covers for cracks and breaks. Occasionally remove the covers and see whether the pilot light bulbs are secure in their sockets. Inspect the control panels for loose knobs and switches.

Adjust (A). Adjust the zero-setting of meters if found to be incorrect. Follow the specific instructions given below.

Clean (C). Clean each cabinet including the control panel, outside and in, with a clean dry cloth. Clean the meter glasses and control knobs with a clean dry cloth.

Lubricate (L). Door hinges and latches need little lubrication, but if inspection reveals that they are becoming dry, apply a small amount of instrument oil. All excess oil should be removed with a clean dry cloth.

Meters

Meters are extremely delicate instruments and must be handled very carefully. They require very little maintenance, but, because they are precision instruments, they cannot be repaired in the field. A damaged meter should be replaced with a spare; a defective meter returned to the maker for repair.

Inspect (I). Inspect the leads and connections to the meter. Check for loose, dirty, and corroded connections. Also check for cracked or broken cases and meter glasses. Since the movement of a meter is extremely delicate, its accuracy is seriously affected if the case or glass is broken, and dirt and water filter through. If the climate is damp, it is only a matter of time until enough moisture seeps through a crack to ruin the meter movement.

Tighten (T). Tighten all loose connections and screws. Any loose meter wires should be inspected for dirt or corrosion before they are tightened. The tightening of meter connections requires a special technique because careless handling can easily crack the meter case. To prevent breakage, firmly hold the hexagonal nuts beneath the connecting lugs while the outside nut is being tightened. This permits the tightening of the connection without increasing the pressure of the head of the stud against the inside of the meter case.

Clean (C). Meter cases are usually made of hard highly polished Bakelite, and can be cleaned with a dry cloth. If cleaning is difficult, the cloth should be dampened with cleaning fluid. Dirty connections may be cleaned with a small stiff brush dipped in the cleaning fluid or with a small piece of cloth dipped in the solvent. It should be emphasized that solvents do not remove dirt entirely from hard surfaces. Some of the dirt remains in a softened state and must be removed with a damp cloth. Corroded connections are cleaned by sanding them lightly with a very fine grade of sandpaper, such as #0000. After they are cleaned, the connections should be wiped carefully with a clean cloth.

Adjust (A). Normally, all meters should indicate zero when the equipment is turned off. The procedure for setting a meter to zero is not difficult. The tool required is a thin-blade screw driver. Before deciding that a meter needs adjusting, tap the meter case lightly with the tip of one finger. This helps the needle overcome the slight friction that sometimes exists at the pointer bearings and prevents an otherwise normal unit from coming to rest at zero. If adjustment is needed, insert the tip of the screw driver in the slotted screwhead located below the meter glass and slowly turn the adjusting screw until the pointer rests at zero. Observe following precautions: View the meter face and pointer full on and not from either side. Avoid turning the zero-adjust screw too far, as the meter pointer may be bent against the stop peg or the spring may be damaged. Zero adjustments should not be made for several minutes after shutdown.

Pilot Lights

Pilot lights are used to indicate that power has been applied to a circuit or that a circuit is ready for power to be applied. They are easily removed and replaced. The colored pilot light covers should be removed carefully, lest they be dropped and broken. The maintenance of pilot lights presents no special difficulty, but the following instructions are given for general guidance.

Inspect (I). Inspect the pilot light assembly for broken or cracked pilot light shields; loose bulbs; bulbs with loose bases; loose mounting screws; and loose, dirty, or corroded connections.

Tighten (T). Tighten all mounting screws, and resolder any loose connections. If the connections are dirty or corroded, they should be cleaned before they are soldered. Loose bulbs should be screwed tightly into their bases. Broken or cracked pilot light shields may sometimes be temporarily repaired by joining the broken or cracked pieces with a narrow piece of friction tape. Replace them as soon as possible; also replace broken or burned-out pilot light bulbs as soon as possible. While the removal of a bulb may sometimes be difficult, the process is made simple by folding a small piece of friction tape over the top of the bulb and pressing firmly from the two sides. After the tape is attached, the bulb can be unscrewed and removed from the socket. The socket connections are, of course, inspected while the bulb is out. A new bulb can be replaced with the fingers, but if difficulty is experienced, use friction tape to grip the glass envelope of the bulb.

Clean (C). The pilot light shield, the base assembly, and the glass envelope of the light bulb should be cleaned with a clean dry cloth. Clean accumulated dust or dirt from the interior of the socket base with a small brush. Corroded socket contacts or connections can be cleaned with a piece of cloth or a brush dipped in cleaning fluid. The surfaces are then polished with a dry cloth. Clean contacts and connections are important.

Plugs and Receptacles

There are two main types of plugs and receptacles used to interconnect the various components. The first type of plug is used with a coaxial line and consists of a metal shell with a single pin in the center insulated from the shell. When the plug is inserted into the receptacle, this pin is gripped firmly by a spring connector. There is a knurled metal ring around the plug which is screwed onto the corresponding threads on the receptacle; while the female part is in the plug. The insulation in these plugs is much heavier in order to withstand the voltage. The second type of plug is used for connecting multiconductor cables. The plug usually consists of a number of pins insulated from the shell which are inserted into a corresponding number of female connectors in the receptacle, although in some cases the plug has the female connectors in it and the male connectors are in the receptacle. This type of plug usually has two small pins or buttons which are mounted on a spring inside the shell and protrude through the shell. When the shell is properly oriented and placed in the receptacle, one of these pins springs up through a hole in the receptacle, firmly locking the plug and receptacle together. When it becomes necessary to remove the plug, the other pin is simply depressed and the plug removed. Connections between all plugs and their cables are made inside the plug shell. The cable conductor may either be soldered to the pin or there may be a screw holding the wire to the pin. Remove the shell if it is necessary to get at these connections for repair or inspection. Loosen the screws if there is a clamp holding the cable to the shell. In some cases, it is found that the shell and plug body are both threaded; then the shell may simply be unscrewed. Usually there are several screws holding the shell. These are removed and the shell is pulled off.

Inspect (I). (1) The part of the cable that was inside the shell for dirt and cracked or burned insulation.

(2) The conductor or conductors and their connection to the pins for broken wires; bad insulation; and for dirty, corroded, broken, or loose connections.

(3) The male or female connectors in the plug for looseness in the insulation, damage, and for dirt or corrosion.

(4) The plug body for damage to the insulation and for dirt or corrosion.

(5) The shell for damage such as dents or cracks and for dirt or corrosion.

(6) The receptacle for damaged or corroded connectors, cracked insulation, and proper electrical connection between the connectors and the leads.

Tighten (T). (1) Any looseness of the connectors in the insulation, if possible; if not, replace the plug.

(2) Any loose electrical connections. Resolder if necessary.

Clean (C). (1) The cable, using a cloth and cleaning fluid.

(2) The connectors and connections using a cloth and cleaning fluid. Use crocus cloth to remove corrosion.

(3) The plug body and shell using a cloth and cleaning fluid, and crocus cloth to remove corrosion.

(4) The receptacle with a cloth and cleaning fluid if necessary. Corrosion should be removed with crocus cloth.

Adjust (A). The connectors for proper contact if they are of the spring type.

Lubricate (L). The plug and receptacle with a thin coat of Vaseline if they are difficult to connect or remove. The type of plug with the threaded ring may especially require this.

Part 6

TECHNICALLY SPEAKING

INTRODUCTION

As has been mentioned several times in this handbook, it is not our purpose to duplicate or rewrite any of the already excellently presented technical phases of radio in other books. The content of this section is technical in nature, but is slanted primarily to allow a clearer insight of the why and wherefore of operating procedures as presented in the first four sections. In addition to this, there are a number of technical matters of outstanding interest to broadcast operators that have not previously been written in the language of the average technician who need not necessarily be a mathematical wizard. It is hoped that the following pages will prove helpful in presenting an understandable picture of the field of broadcast engineering to the operating personnel and to students of the broadcasting arts.

Chapter 18

CONTROL ROOM AND STUDIO EQUIPMENT

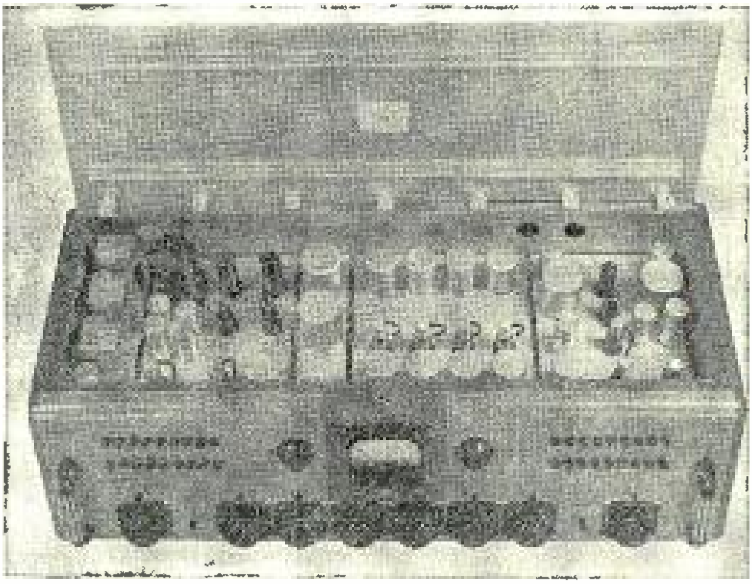
CONTROL-ROOM EQUIPMENT may become very complex in number of circuits and control functions, but is designed and installed to achieve a practical easily operated setup that allows foolproof switching and flexibility of functions. Briefly, the general requirements are as follows:

(a) Amplifiers for stepping up the minute electric energy produced in the microphone by the program sound waves.
(b) Switching and mixing arrangements to allow selection of proper program source and blending of microphone outputs for desired program "balance."
(c) Facilities for "auditioning" or rehearsing a program to follow.
(d) Terminations of inputs and outputs of all amplifiers on jack panels to allow rapid "rerouting" of the signal in case of trouble in any one amplifier or channel.
(e) Incoming and outgoing line terminations on jack panels to permit flexibility in receiving or transmitting the signal in any way desired.

Fig. 18-1 illustrates one type of commercial control-room console which contains all amplifiers and relays within the cabinet. The power supply comes in an external wall mounting unit. This console provides amplifiers, control circuits, and monitoring equipment necessary to handle two studios, announce booth microphone, two transcription turntables, control-room announce microphone, and six remote lines. In addition to this, means are provided for simultaneously auditioning or broadcasting from any combination of studios, turntables, or remote lines. The volume indicator is a standard vu meter which has an adjustable attenuator mounted on the panel to the right of the instrument allowing a 100% deflection of the pointer on the scale to be calibrated for +4, +8, +12, and +16 vu.

The technical layout of this speech input equipment is as follows:

Four preamplifiers connected to four of the six mixers on the panel in center position serve to amplify the outputs of the microphones. A 3-position key switch is in the input of the fourth preamplifier to allow its operation from a microphone in the studio, announce booth,

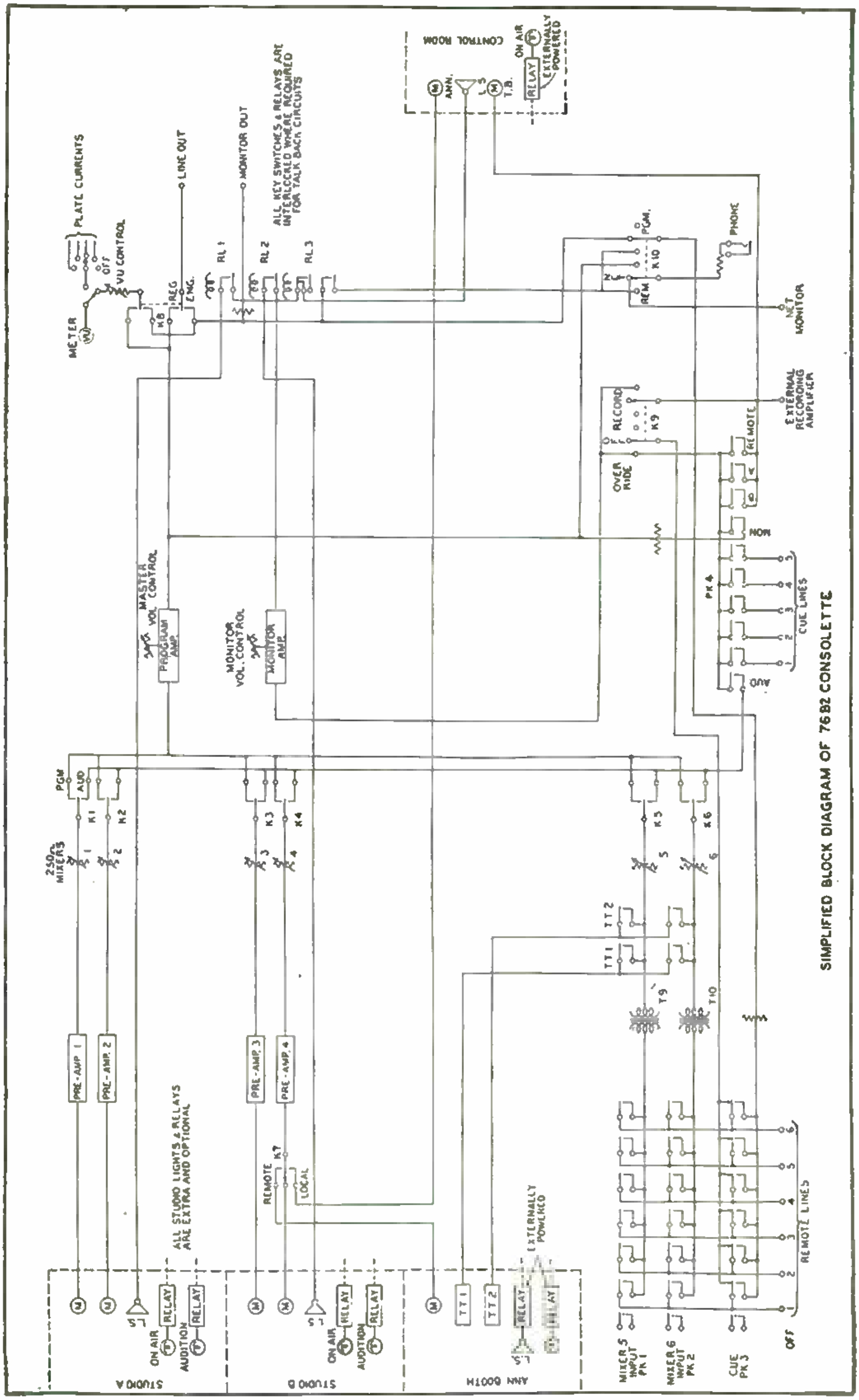


RCA Photo

Fig. 18-1. One type of commercial control-room console containing all amplifiers and relays within the cabinet.

or control room. The outputs of the mixers connect to lever keys to provide switching to the regular program amplifier for broadcasting or to the monitor amplifier for auditioning. When these key switches are operated they also serve to disconnect the studio loudspeaker to prevent feedback, and operate "on-air" light relays. The fifth and sixth mixers may be connected by means of push keys to any of six remote lines or the two turntables. Other push keys on the panel provide circuits for feeding the cue to remote lines and for bringing in monitoring circuits such as transmitter or master-control (where used) outputs. The monitoring amplifier may be used for the program amplifier in emergencies by operating the proper key. Means are also provided to supply power to the preamplifiers from the monitoring amplifier in case of power supply failure to the preamplifiers.

This is an example of the extreme flexibility and emergency provisions designed into control-room equipment. Fig. 18-2 is a simplified schematic diagram of a typical installation. The "Override-Record" switch permits a remote operator to call in from any of the six remote lines and override the program on the control-room speaker. The



Courtesy RCA

Fig. 18-2. Simplified block diagram of a control-room installation.

"Record" position of this switch furnishes a signal source for an external recording amplifier or other destination.

Control-room equipment and layout vary over a considerable range and variety from composite setups through regular commercial consoles and custom-built equipment. Fig. 18-3 illustrates the type of studio control consoles at WHK in Cleveland.

At WHK, each studio has its own control room. The consoles for all the studios are identical and were built by the WHK engineering staff. This was not done for economic reasons, but because none of the commercially available consoles were suitable for the particular needs at hand. Each console is set up to handle six microphones normally, with provision to patch in as many more as needed. Each input has a preamplifier and mixing is done at high level. All mixers in studio control and master control at WHK are the vertical type, which may be a surprise to some readers.

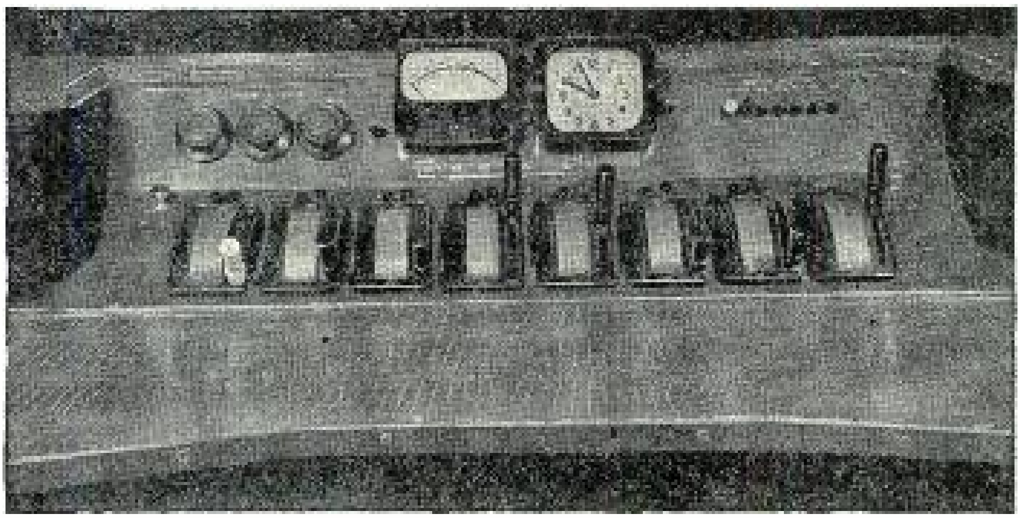


Fig. 18-3. The handles of the faders on the studio consoles at Station WHK are vertical, making them easier to handle than rotary faders.

Vertical faders have several advantages wherever space is no consideration. More vertical faders can be handled competently with one hand than rotary faders. The amount which a vertical fader is opened is instantly and graphically apparent; that is, the eye can tell whether it is ½, ⅔, or ¾. Regardless of how a rotary fader is marked, it takes some concentration to determine how far open it is, provided the knob has not turned on the shaft. Every man who ever worked at WHK and then worked somewhere else, has agreed that the vertical type is much easier to use, especially on large programs.

In addition to the microphone inputs there is a high level input into which master control can patch any desired program source. This allows smooth handling of multisource programs. As a matter of fact, any fader may be used as a high level input by patching the program in after the preamplifier. It is standard practice at WHK to have every piece of equipment come out on jacks. All equipment which is normally used together is connected through normal through jacks. Then there is a master fader which controls the console output. The fader system is a complete unit hooked up between the preamplifiers and the line amplifier, and has some interesting possibilities in case of trouble. Fig. 18-4 illustrates the basic mixing circuit.

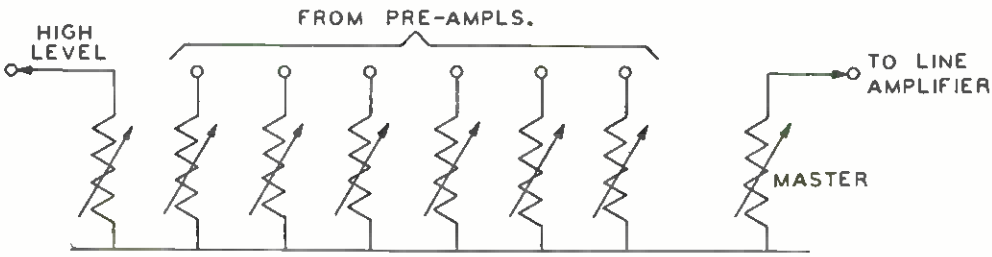
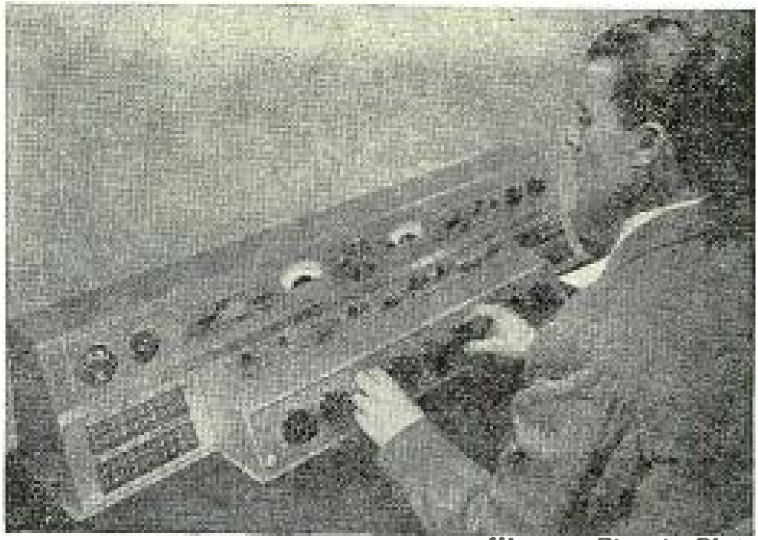


Fig. 18-4. The basic mixing circuit of the fader system used in the console shown on the opposite page.

All faders whether used for high level, microphone, or master, are exactly alike, so that anyone can be used for any purpose. When the top of the fader is used as an input, it deposits the program onto a bus, minus the vu loss of the fader setting. By using the top of the fader for an output, the program on the bus is fed to any desired place minus the vu loss of the fader setting. The faders are all 600 ohms in and 600 ohms out. If the master fader in the diagram of Fig. 18-4 went out of order, any of the microphone faders not in use, or the high level mixer, could be patched to the line amplifier and would become the new master fader.

There are two line amplifiers in each console, one of which is wired through normal jacks and one which may be patched to replace the regular. There are two power supplies, either one of which can be selected by a change-over switch. There is also a monitor amplifier, a p-a amplifier with separate gain control, and a communications amplifier for talking to studio or master control. The microphone and speaker of the communication system are mounted flush in the surface of the console. All amplifiers are vertically mounted in the console with doors which expose the tubes on one side or the bottom of the amplifier on the other. This makes for easy servicing. Characteristics of all equipment except the communications portion, is plus or minus 0.5 db from 30 to 15,000 cycles. For the convenience of the operator there are six monitor buttons by means of which he can select his own console output, master control output, final station monitor, network,



Western Electric Photo

Fig. 18-5. This type of control-room console is more usual than that illustrated in Fig. 18-3.

and two spares into which anything else may be patched. None of these buttons affect the on-the-air program. There is also a pilot light system which indicates to the studio operator every place his program is going, local station, network, audition room, executive's office, etc. Fig. 18-5 illustrates another type of control-room console.

BROADCAST MICROPHONES

The microphone, first gateway through which all sounds are passed on to the "mixing" network of the control console, is the most important instrument under the direct supervision of the control operator or producer.

Much depends on the characteristics and operational interpretation of this first link. First, it must have a wide frequency range. High-fidelity amplifiers would be useless without high-fidelity microphones. Second, it must have very low internal noise level for the wide dynamic range necessary to please exacting listeners, and to meet engineering standards of broadcast quality transmitters and receivers.

Next, it must possess a definite and dependable response pattern in relation to angle of incidence of the sound waves so that pickup areas may be properly defined. In broadcasting, we are concerned with wanted and unwanted sounds, and all shades in between. Aurally correct blending of musical and vocal sounds involves correct usage of the microphone characteristics as much as the proper manipulation of the mixing controls on the control panel.

Since, in nearly all installations of broadcast studios it is necessary for the microphone to be placed a considerable distance from the preamplifier, a low output impedance is desirable. This is important since the microphone cable possesses distributed capacitance which would seriously affect the higher frequencies if a high impedance were used. The most common preamplifier input impedances for broadcast use are 30, 50, and 250 ohms. All microphones, regardless of type, are of the same impedance at any given broadcast station. A ribbon microphone, condenser, dynamic, or combination type may be plugged into the microphone inlet without adjustment of impedance values. Output level is very low in most high-quality microphones, ranging from about minus 55 db to minus 90 db where the reference level is one milliwatt for a sound pressure of 10 dynes per square centimeter. Frequency response is comparatively good over a range of 30 to 15,000 cycles. Internal noise level is well under 50 db below no signal conditions.

Microphone Fundamentals

Fig. 18-6 shows the primary function of a "pressure" type microphone such as the dynamic, condenser, or crystal type. Sound waves

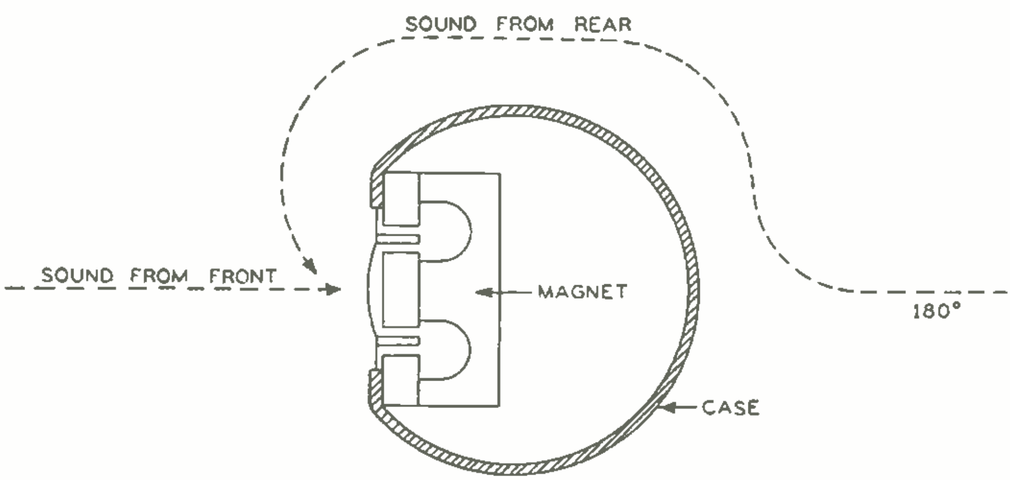


Fig. 18-6. The diaphragm of the "pressure" type microphone always moves in the same direction whether the sound comes from the front or rear.

of alternate condensations and rarefactions of air entering the microphone cause the pressure variations of the diaphragm to actuate the moving element between the magnetic pole pieces, which in turn generates a small electric current in accordance with the sound waves. The diaphragm always moves in the same direction regardless of the initial direction of the sound.

Fig. 18-7 illustrates the function of the "ribbon" or "velocity" microphone. This instrument consists essentially of a thin metallic ribbon

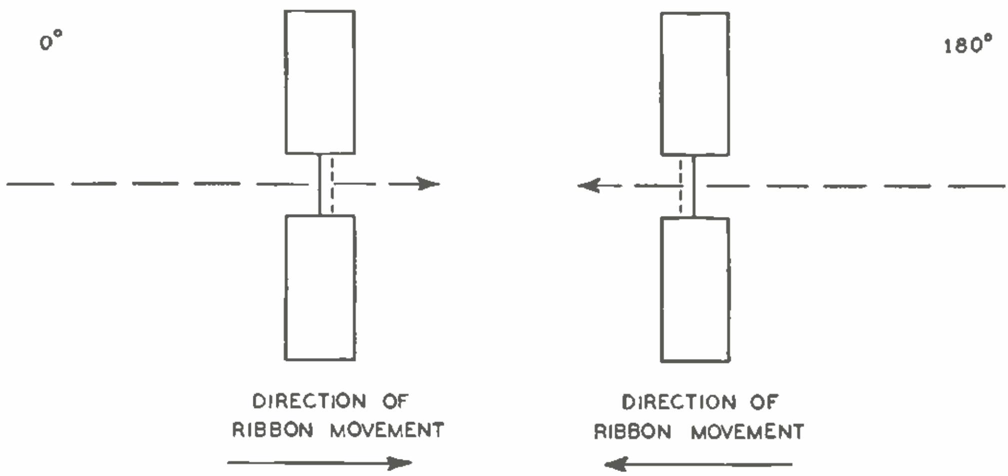


Fig. 18-7. Sound coming from the front or rear (0° or 180°) of the "velocity" microphone actuates the diaphragm, but sound coming from the side (90°) does not cause the diaphragm to vibrate.

suspended between two magnetic pole pieces without a diaphragm or associated cavity. As the sound waves strike the ribbon from one direction, the element is caused to move since a pressure difference exists in any sound field between any two given points. Since this differential pressure exists between the front and back of the ribbon, the ribbon will naturally move in the direction of diminishing pressure. This rate of change of pressure with distance is called "pressure gradient" and is the principle upon which the ribbon microphone operates. As observed from Fig. 18-7, sound approaching from the opposite direction causes the element to move in the opposite direction according to the pressure gradient principle. The ribbon can move only along the axis perpendicular to its surface, and sound waves entering from the side 90° from either "face" of the microphone cause an equal pressure on both sides, hence zero response. Thus this microphone gives the conventional "figure eight" response pattern, in comparison to the nondirectional response pattern of the strictly "pressure" type microphone.

Fundamentally, then, we have two distinct primary principles of microphone operation, the "pressure," or nondirectional type, and the "pressure gradient," or bidirectional type. These two functions may be combined to achieve a third kind of response pattern, the unidirectional microphone.

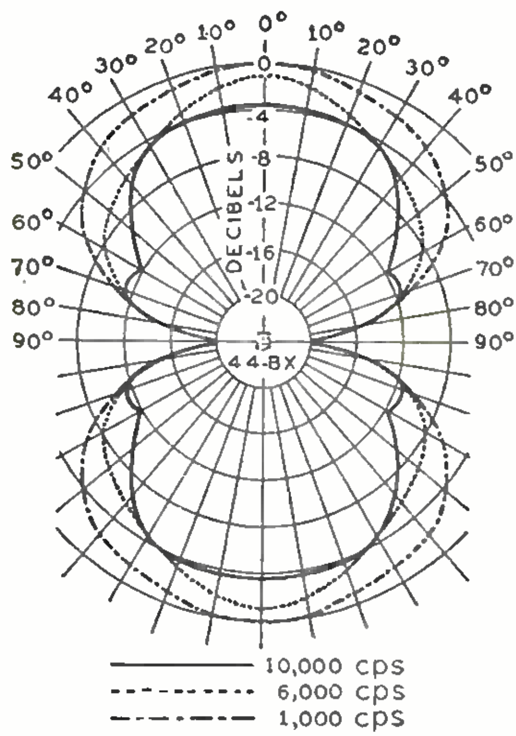
The unidirectional, or one-direction response microphone is a very important instrument in broadcasting pickup technique. This microphone consists essentially of a dynamic and ribbon element in one assembly. The coil and ribbon are connected in series with the wires poled so that the outputs of the two elements cancel for sound coming from one direction, and augment one another for sound from the other direction. Remember that the ribbon moves in the opposite direction from that of the coil when sound waves impinge from one direction

RCA Photo

Fig. 18-8, above. The ribbon or velocity type of microphone.

Fig. 18-9, below. The family of response curves for the ribbon microphone showing how the response varies for three frequencies at different angles.

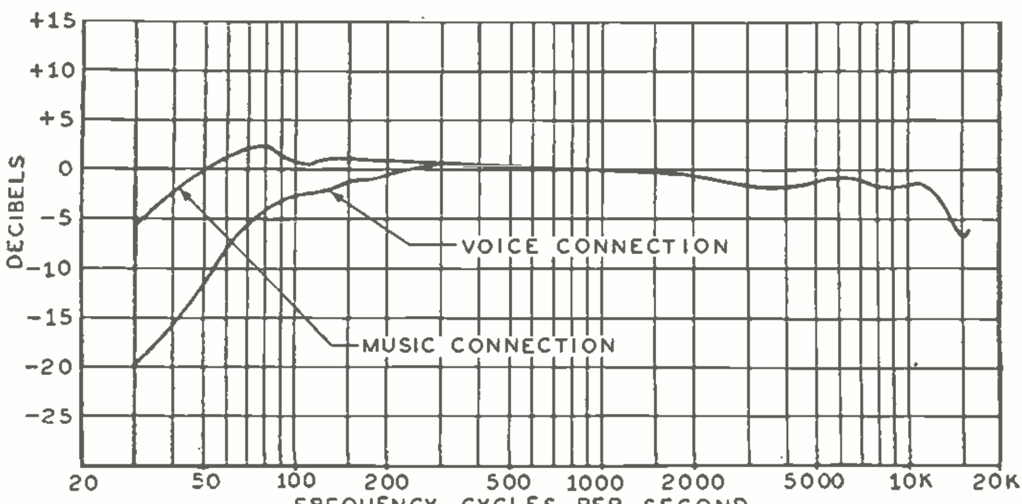
Courtesy RCA



which causes an equal and opposite voltage to be generated in the output (hence zero voltage), whereas the movements are in the same direction for sound waves on the opposite side of the microphone.

The Ribbon Microphone

The ribbon or "velocity" microphone is one of the most popular types of microphone used in broadcast studios. Fig. 18-8 shows a ribbon microphone, the associated response curve is shown in Fig. 18-9. This type of microphone is free from effects of cavity resonance, diaphragm resonance, or pressure-doubling effects since the moving element is a metallic ribbon suspended so as to vibrate freely between the pole pieces of the magnet. This microphone, as are most modern microphones, has a "voice" and "music" connection to achieve the best possible frequency characteristic for either vocal or musical pickups. The frequency-response curves for both connections are shown in Fig. 18-10.



Courtesy RCA

Fig. 18-10. The ribbon microphone has a "voice" connection and one for "music" to obtain the best response for either type. The frequency response curves for either connection are reproduced above.

As was mentioned in the section on studio setup technique, the ribbon microphone tends to accentuate the low frequencies under close talking conditions due to the pressure-gradient characteristic. This is because, although the pressure is independent of frequency, the pressure gradient is not and it becomes comparatively large for points close to the source in relation to the wavelength. For this reason, the speech "strap" is used to equalize the low-frequency "boom" under close talking conditions. When the same microphone is used for musical pickup and announcer, the "music" connection should be used and the announcer should work two feet or more away from the face of the microphone.

Variable Pattern Microphones

Fig. 18-11 illustrates the structure of the Western Electric 639B cardioid microphone which has provisions to provide a number of re-

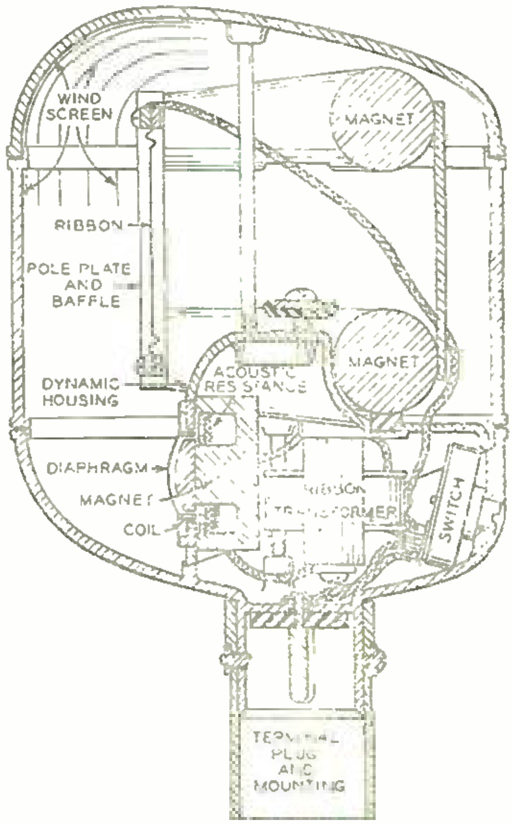
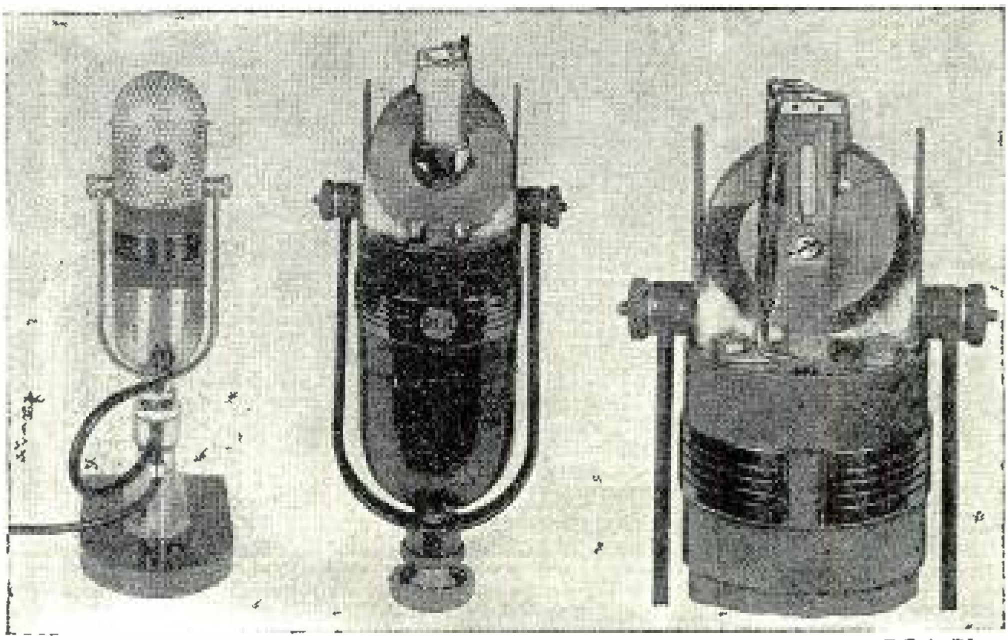


Fig. 18-11. The internal structure of the cardioid microphone which provides a number of response patterns by means of a six-position switch in the rear.

Courtesy Western Electric Co.

sponse patterns by a six-position switch. It consists of a special ribbon and magnet structure in combination with a dynamic unit. The housing of the dynamic structure encloses the ribbon transformer, electrical equalizer, and selector switch. In the "cardioid" position, the ribbon and dynamic element are used together to obtain the familiar "cardioid" or unidirectional pattern, as described in a previous paragraph. It may also be used as a ribbon microphone only with bidirectional characteristics, and dynamic only with nondirectional response, as well as three other combinations of response patterns.

The new RCA polydirectional microphone Type 77-D consists of a single ribbon element and a variable acoustic network. One side of the ribbon is completely closed by a connector tube coupled to what is known as a damped pipe or labyrinth. In the connector tube directly behind the ribbon is a variable aperture which adjusts the directional characteristics of the microphone. When this opening is large, the back of the ribbon is exposed, as is the ordinary velocity microphone, and a bidirectional response pattern is obtained. When the aperture is completely closed, the acoustic impedance of the network is infinite and a nondirectional pattern is achieved similar to a dynamic microphone. The opening is continuously variable thus enabling the operator to achieve a large variety of response patterns. Fig. 18-12 is a rear view showing the slotted shaft-control adjustment, Fig. 18-13 is a front view of the ribbon assembly, and Fig. 18-14 is a rear view of the same assembly.

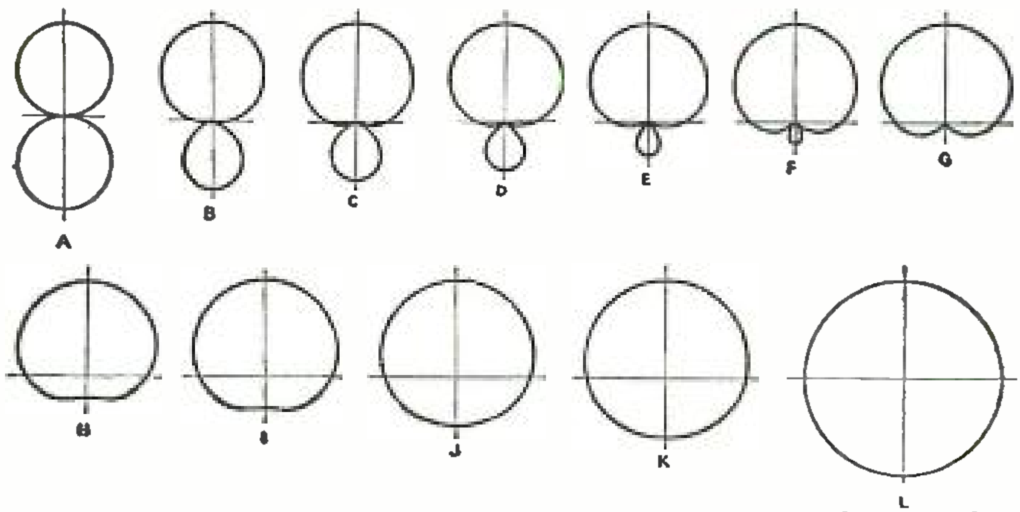


RCA Photo

Figs. 18-12, 18-13. 18-14, left to right. Rear external view of the polydirectional microphone. The middle view is the front of the ribbon assembly and the rear view is at the right.

The plate of the slotted adjustment is marked "U," "N," and "B" for "unidirectional," "nondirectional" and "bidirectional" designations, and three other markings are used to provide reference points for other obtainable patterns. Fig. 18-15 gives the reader an idea of the number of different patterns that may be obtained by the aperture adjustment of this instrument. The bidirectional pattern is approximately that of *C*, the unidirectional pattern that of *G*, and the nondirectional that of *J* or *K*.

The lower half of the case of the 77-D contains the associated acoustical labyrinth, the output transformer tapped at 50/250/600 ohms,



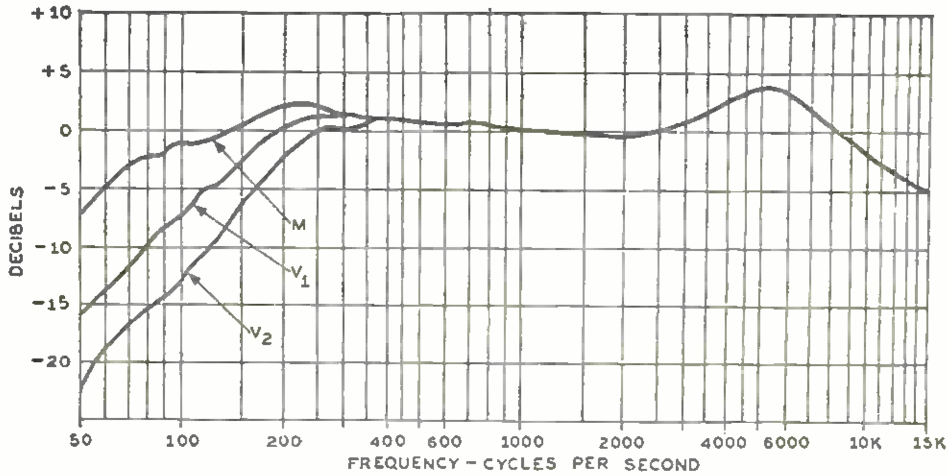
Courtesy RCA

Fig. 18-15. Various response patterns obtainable with the polydirectional microphone.

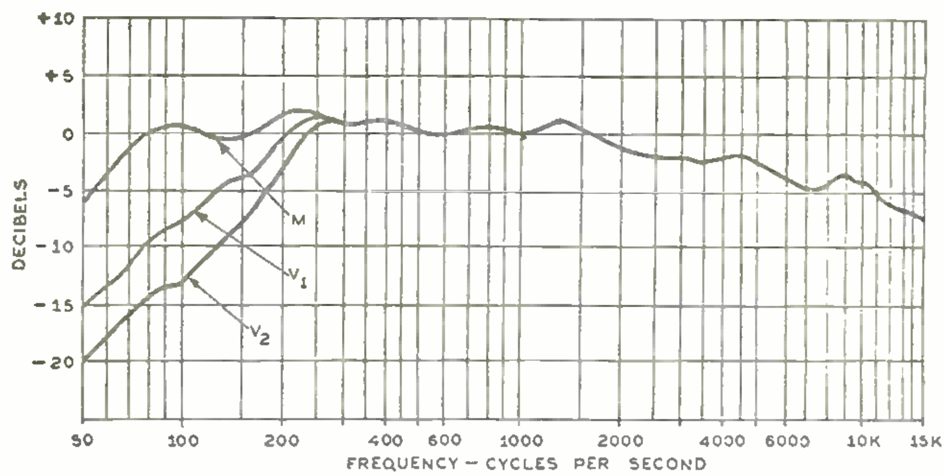
and a selector switch for voice or music. The frequency response curves for either connection and for "U," "N" and "B" patterns are illustrated in Fig. 18-16 on the next page.

OUTPUT CIRCUITS AND LINE EQUALIZATION

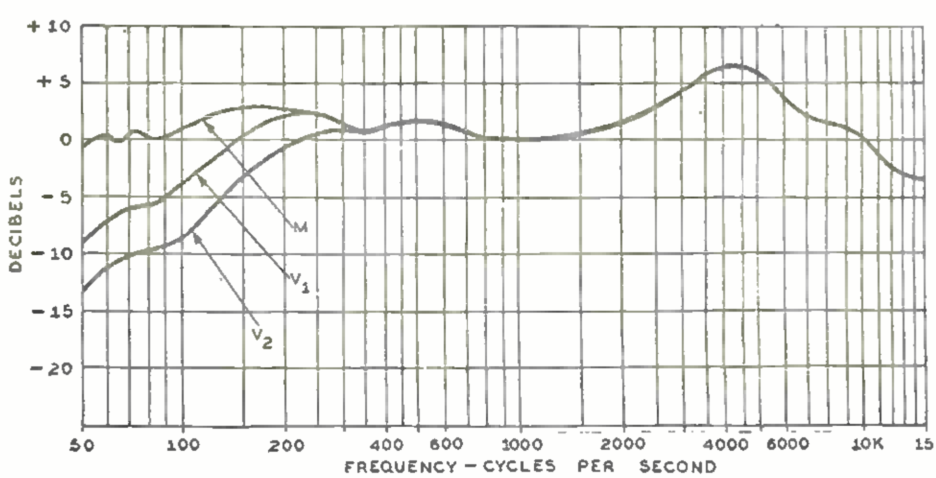
The line amplifier at the studio is always "isolated" from the line by a pad and a repeater coil. The necessity for this becomes apparent if the reader visualizes what would occur if such a means of coupling was not employed. An amplifier with an output of 600 ohms to match a 600-ohm line, if connected directly to the line, would have its frequency response materially affected by the length and characteristics of the line itself. Due to the distributed inductance and capacitance of the line, a different impedance would exist at every different frequency. For this reason, a pad of at least 10-db attenuation is always used to load the output of the amplifier, followed by what is known as a "repeating" coil. The control-room equipment is nearly always "balanced to ground" to prevent hum pickup and cross talk, in which case the repeat coil has a center tap to ground on both primary and secondary. When the equipment is single ended (one side grounded), the repeat coil is single ended on the primary side and balanced on the secondary or line side in order to provide a suitable connection of unbalanced to balanced conditions.



(A)



(B)



(C) *Courtesy RCA*

Fig. 18-16. When the switch of the polydirectional microphone is set at "U," the response curve of (A) is obtained. Response curves for bidirectional "B" and nondirectional "N" switch settings are shown in (B) and (C) respectively.

Operators and technicians are frequently confused when looking at the schematic diagram of the control-room installation to find a 600-ohm to 150-ohm output pad which is intended to feed a 600-ohm line. This arrangement is often used, however, where the line to be fed is comparatively short and unequalized. It should be remembered that the capacitive effect along the line attenuates the higher frequencies. Using a mismatch of this kind provides a beneficial equalizing effect which tends to compensate for the characteristics of the line. This arrangement is also often used on lines that *are* equalized, the amount of equalization necessary being less, with less insertion loss due to a great amount of equalization.

Line Equalization

Although the telephone company usually equalizes the incoming network lines and regular broadcast lines from studio to transmitter, it is many times beneficial to equalize lines from remote pickup points where the cost of high-class line service is not practical to the station. For this purpose most stations have an equalizer of adjustable characteristics in the control room which may be used for this purpose.

Fig. 18-17 illustrates a typical setup for equalizing a broadcast line. The signal source is a steady tone from an audio oscillator which is

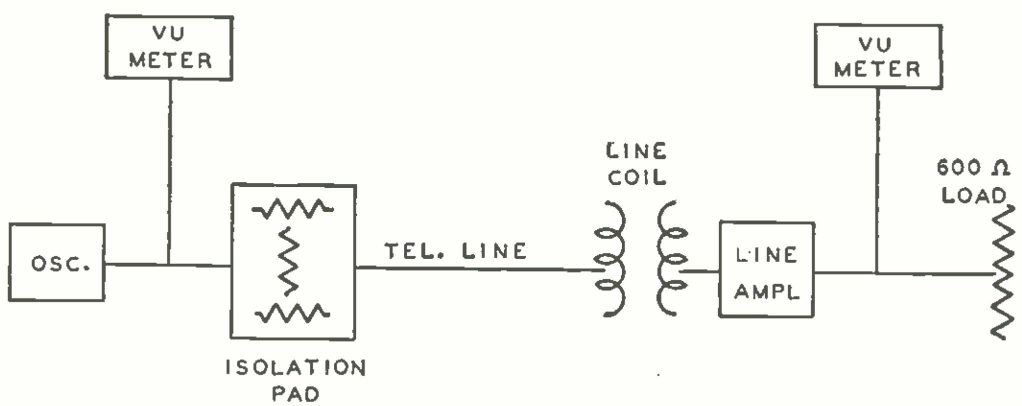


Fig. 18-17. Block diagram for a typical setup for equalizing a broadcast line.

terminated in an isolation pad. The same load at any frequency must be presented to the volume indicator and this instrument should therefore be bridged on the oscillator side of the pad. The equalizer must be on the line side of the coil at the receiving point, as shown in Fig. 18-17.

A 1000-cycle tone is usually used as the reference frequency. The oscillator is set at this frequency and fed to the line at O-vu level. The gain of the receiving amplifier is adjusted to give O-vu reading at that point. The oscillator is then adjusted to 100 cycles, 1000, 3000, and 5000 cycles with constant level maintained at each frequency, and the equalizer adjustment made at the receiving point to compensate as much as possible for the line characteristics at each frequency. This will determine the approximate setting of the equalizer, after which finer adjustments may be made over the entire frequency range.

FREQUENCY RUNS OF STUDIO EQUIPMENT

Fig. 18-18 is a simplified block diagram of a studio control-room setup for purposes of illustrating a convenient method of running

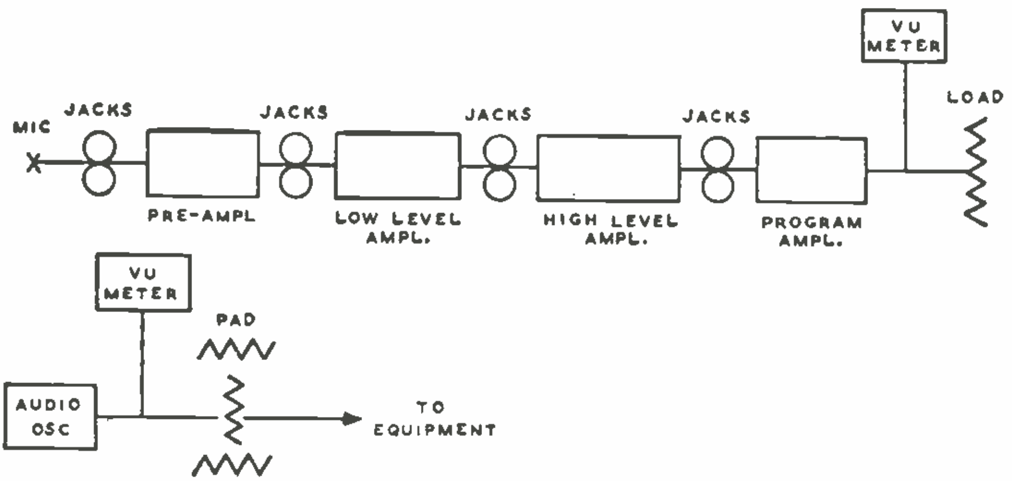


Fig. 18-18. Block diagram of a studio control-room setup for running frequency-response curves on the equipment.

frequency-response curves on such equipment. The over-all frequency response is first determined by plugging the output pad of the audio oscillator into the input of the preamplifier and noting the final vu meter reading at 1000-cycles reference point. On this initial reading, both meters are driven to O-vu deflection. The oscillator output level is now held constant over the entire frequency run and the number of vu deviation from 1000-cycle reference jotted down on paper or plotted on a graph. Should the frequency response not be up to par over the entire run, the frequency run of the main program amplifier may be made, then going back down the line until the faulty stage is made apparent by noting where the frequency response begins to deviate from normal.

NOISE AND DISTORTION MEASUREMENTS

A typical noise and distortion meter is described in Part 4 and the appendix for use on broadcast transmitters. This equipment may be also used on control-room equipment. The diode detector is removed from the circuit by a switch providing a connection through a balanced input transformer for measurements on balanced audio equipment, or for connection to the input attenuator for use with unbalanced circuits. The rest of the procedure is then the same as that described for transmitter measurement. The same method of isolating noise or distortion-introducing stages may be used here as described above on frequency runs.

TELEPHONE COMPANY LINE SERVICES

Line services offered by Bell Telephone and American Telephone and Telegraph (AT&T) are divided into two general categories:

Metropolitan Area Circuits (Bell Telephone) which provide service for remote pickup points and studio-to-transmitter loops.

Toll Circuits (AT&T) composing the national network of circuits and long lines outside the metropolitan area.

The metropolitan area circuits are divided into services of the following general limitations:

(a) Frequency range of 35 to 8000 cycles per second within plus or minus 1 db of 1000-cycle reference, and a volume range of 40 db. This service is sometimes used for studio-to-transmitter program loops.
(b) Frequency range of 100 to 5000 cycles per second within plus or minus 2 db and a volume range of 40 db. This is the more common studio-to-transmitter service, and sometimes used for remote pickup points.
(c) Nonloaded commercial telephone service and unequalized, for use of remote pickup points.

Toll circuits are divided into general classifications such as high-quality, medium-quality, and speech-only services as follows:

(a) Frequency range of 100 to 5000 cycles and volume range of 30 db. This is the normal service of national network hookups.

(b) 150 to 3700 cycles, sometimes used where not enough time was available to install the higher quality service.

(c) Speech-only service of about 250 to 2750 cycles. Also often used for intercommunication between long-distance points and emergencies.

Chapter 19

THE BROADCAST STUDIO

THE ENDEAVOR to realize high-fidelity transmission of broadcast programs is definitely not new; it has been the goal of at least some engineers since the earliest days of broadcasting. The realization of over-all high-fidelity service, however, includes the receiving set in the home, and it has not been until very recently that the "average" set in the medium price market was worthy of the extraordinary efforts of some broadcasters to render high-fidelity service. Conversely, it is apparent at the present time that with a good receiver, noticeable differences in fidelity characteristics of different stations within the range of the receiving position are observed by the critical listener.

If the present state of development in broadcast amplifier equipment is taken as the sole criterion, then high-fidelity transmission is truly here. Frequency response is within 2 db of 1000-cycle reference from 30 to 15,000 cycles, and is limited only by wire-line connecting links in amplitude-modulation (a-m) installations, or not at all in frequency-modulation (f-m) installations. Noise level at the antenna of the transmitter is at least 60 db below 100% modulation, and dynamic range capability is at least 40 db for a.m. and 70 db for f.m. Unfortunately, however, the actual existence of high-fidelity depends on many factors other than the a-f and r-f amplifiers associated with the installation. These amplifiers, according to the ideas of some, form the "heart" of the transmission system insofar as high fidelity is concerned. Actually, they are merely a link in the chain of necessary functions of broadcasting a program, and are no more important to fidelity than the other links, as Fig. 19-1 demonstrates.

In order to focus attention on the possible weak links, by eliminating the amplifiers, as such, there remain: program and talent, production technicians responsible for pickup technique, the studio itself, program producers and announcers, microphones, mixing and switching circuits, control-room, master-control and transmitter operators, wirelines, feeder systems and matching units, antennas, and the limitations

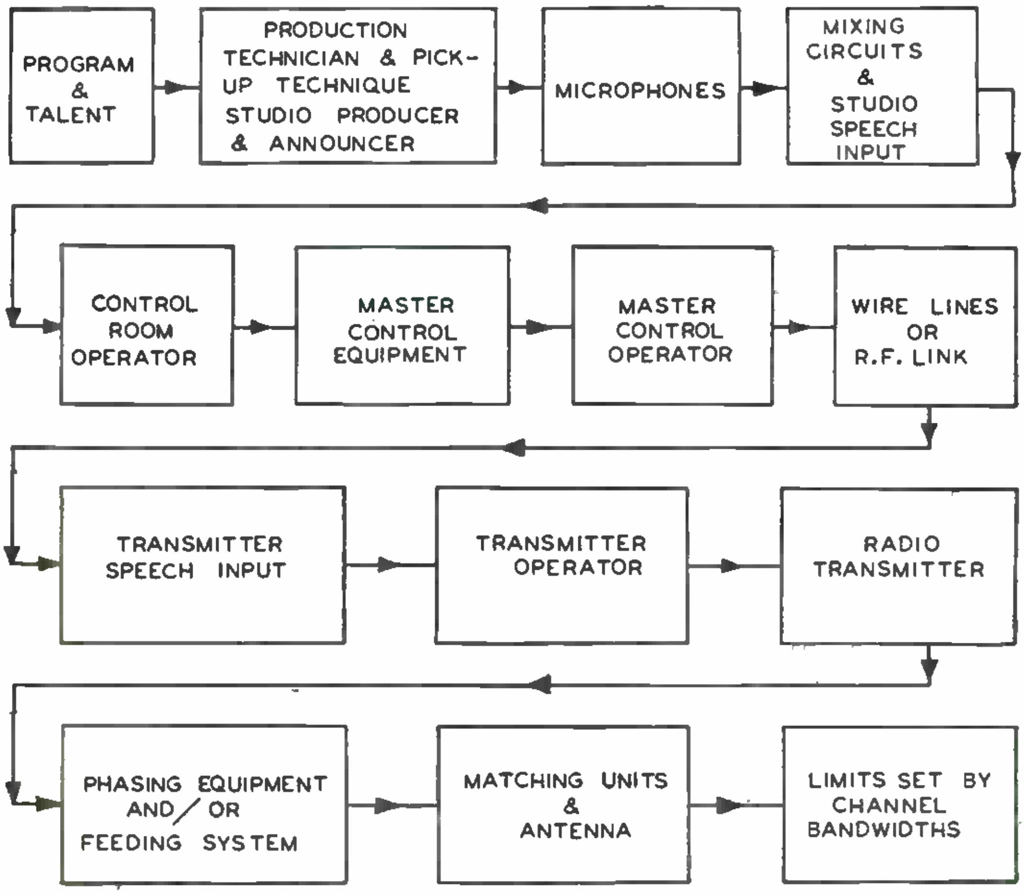


Fig. 19-1. Various links in the chain of putting a program on the air, all of which are important in high-fidelity broadcasting.

set by channel bandwidths subject to government regulations. This presents quite a formidable list, and each item is recognizably inferior to the modern amplifier associated with the broadcast installation in performance. To those familiar with broadcasting, however, it may be shown that the weakest links and those which cause most concern at the present time, are the studio itself, operating personnel, wire-lines, and bandwidth limitations in a-m stations.

The limitations set by wire-line transmission are not serious if considered in relation to the allowable 10-kc channel of the standard broadcast installation. Most lines are equalized to 5000 cycles which is, theoretically, the highest frequency tolerable of any effective strength to prevent adjacent-channel interference. On the other hand, insofar as the relatively small primary coverage area is concerned, the frequency range of modern a-m transmitters (10,000 cycles) if utilized, would allow a marked improvement over present fidelity realization, with class B and C service areas suffering from increased cross talk and interference. Although this situation is a deplorable one, it requires little discussion, in that the problem is primarily one to be solved in the future actions of the FCC.

Thus, there remain two factors to be considered, studio design and operating personnel. It is obvious that the broadcaster could possess high-fidelity equipment from microphone to antenna and still not provide high-fidelity service. In the final analysis, the outcome of any program for a given equipment installation depends entirely on the ability of the technical staff responsible for the operating technique of the equipment. Realizable dynamic range, for instance, which is a highly important factor in high-fidelity transmission, is rarely utilized by station operators. It should be stated here, however, that this is not entirely the fault of operators, but is due rather to a combination of factors including an incomplete correlation between the philosophy of dynamic range and compression amplifiers, inadequate visual monitoring indicators for wide dynamic range, and a confusion of ideas existent among personnel as to the amount of dynamic range tolerable in the home receiver for various types of program content. With the advent of f-m transmission, this problem will become more and more important.

Problems in Studio Design

It is often surprising to discover from a detailed study of the sequence of steps in the development of a certain product, that an indication of a definite direction exists which might well be given the term evolution, and which inevitably indicates a trend that reveals to the searcher an insight into future design of that product. The history of broadcast studio development is interesting not only from this point of view, but also from the viewpoint of establishing the present state of the art as it affects high-fidelity possibilities.

In general the broadcast studio must meet the following requirements:

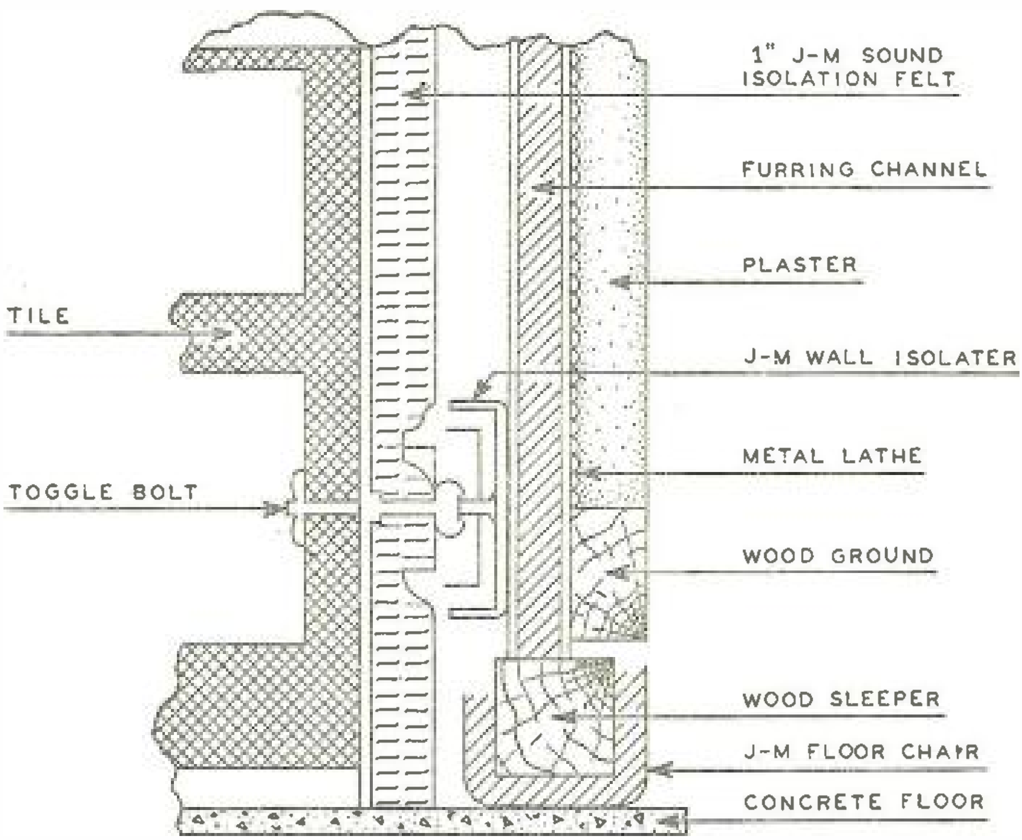
1. Freedom from noise, internal or external
2. Freedom from echoes
3. Diffusion of sound, providing a uniform distribution of sound energy throughout the microphone pickup area
4. Freedom from resonance effects
5. Reverberation reduction such that excessive overlapping of suc-

cessive sound energy of speech articulation or music does not occur

6. Sufficient reverberation such that emphasis of speech and musical overtones is provided to establish a pleasing effect as judged by the listener.

Early Studio Design

In the earliest days of broadcasting, the foremost problems encountered were quite naturally noise and echoes, since "studios" were simply rooms of rectangular shape, with windows of conventional type and walls of ordinary architectural construction. The first steps in



Courtesy Johns Manville Corp.

Fig. 19-2. The "floating studio" type of wall and floor construction.

design procedure were then taken to treat the walls acoustically to prevent echoes and "flutter," and to cover the windows with the same acoustical material. This sufficed for a certain era in broadcasting, provided the operator with control over echoes, and practically isolated the microphone from factory whistles, fire sirens, etc. At that time, this type of studio was entirely adequate to satisfy the fidelity requirements of the program transmission possible with associated transmitting and receiving equipment; indeed the electronic amplification of broadcast programs was so much better than the acoustic model phonograph that the general public thought of the radio as a realization of true high-fidelity reproduction.

With the advent of the dynamic loudspeaker, microphone improvements, higher power and wider band amplifiers, the scope of fidelity possibilities began to broaden considerably. Signal-to-noise ratio was improved, and higher volumes could be handled in the receiver without distortion, resulting in a greater dynamic-range capability, but at the same time adding to the burden of studio design, since extraneous noises picked up at the studio were now more noticeable in the home receiver. This fact led to the "floating studio" type of construction, shown in Fig. 19-2.

The period following saw many phenomenal improvements in broadcast equipment in general, such as 100% modulation of the transmitter with greatly reduced distortion, improvement in syllabic transmission characterstics, reduction of spurious frequencies and ripple level, greatly reduced noise levels in switching and mixing circuits, and nonmicrophonic tubes. Yet, strangely enough, studio design remained nearly stagnant over a period of six or seven years except in isolated cases. Indeed, the rectangular shaped, acoustically deadened studio may be recognized by those familiar with the state of the art today as being the most common type of studio among independent stations, even of very recent installation.

The broadcast engineer found himself faced with many apparent difficulties in studios of this type of construction. The big factor, in a room with parallel walls, is the excessive acoustical treatment necessary to overcome the effect of echoes as mentioned previously. This has resulted, in the past, in extreme high-frequency attenuation and a lack of "liveness" such that the brilliancy of musical programs was completely lacking. The loudness intensity for a given meter reading on the volume indicator is very low for a studio of this type in comparison with that obtained from a modern studio.

The effect on speech, while not satisfactory, is not so pronounced as that on music since speech originates within a few feet of the microphone and requires less reverberation to assure naturalness, whereas the space between the source of the music and the microphone is greater, and many things happen to the musical waveforms that must eventually be translated into perceptions of loudness. This effect obviously leads into complex operational difficulties, requiring a lower "peaking" of voice in relation to music on the volume indicator to obtain a comparative loudness intensity in the receiver at home. Furthermore, microphone placement technique for this type studio is such that a number of microphones must be used for a group of performers, since, if a single microphone is employed, a lack of reinforcement of harmonics and overtones of the instruments results in a thin sound, lacking in body.

Another difficulty resulting from parallel-wall construction is shown in Fig. 19-3, where it may be observed that the angle of incidence of

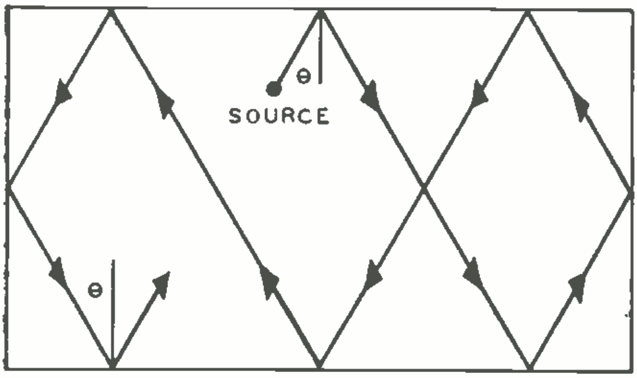


Fig. 19-3. The effect on a sound wave train of parallel-wall construction resulting in undesired resonance effects.
(M. Rettinger: Acoustics in Studios. Proc. IRE, July, 1940. By permission of the Proc. IRE.)

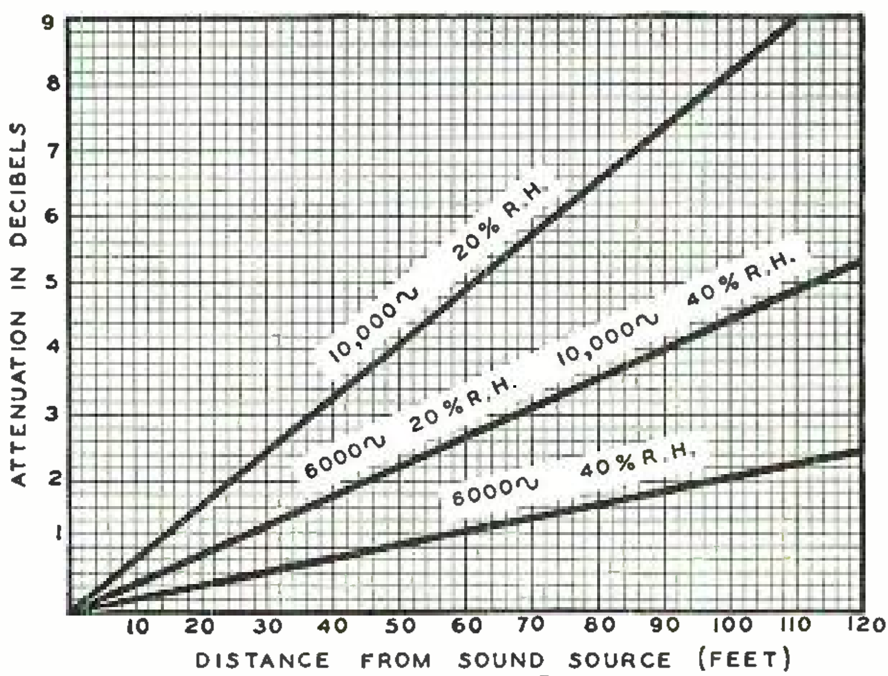
the wave-fronts remains the same no matter how many such reflections occur. Due to the acoustical treatment this reflection (to any great extent) occurs only at the lower frequencies and it may be seen that the nodes would have marked regions of coincident reinforcement, resulting in resonance effects at the lower frequencies, and conditions that would result in diffuse sound distribution are reduced. Thus it becomes obvious that items 3, 4, and 6, as given earlier in requirements for good acoustics, are lacking in studios of this design. In addition, high-frequency response so necessary to brilliancy is reduced, effective dynamic range is inadequate, and operational difficulties are numerous. Thus, it is apparent that the studio becomes the weakest link in the high-fidelity chain in the great majority of broadcast installations today. Exceptions, of course, are the main network studios, and a few independent stations more "production conscious" than the main body of independent broadcasters. It is certainly obvious that the contemplated large scale expansion of f-m service will bring about the need for a revolutionary education in studio requirements for the independent station operator.

Advances in Studo Design

From the foregoing discussion the difficulties to be overcome may be listed as follows:

1. Lack of diffusion of sound
2. Resonance conditions at low frequencies
3. Insufficient reverberation for music
4. High-frequency absorption
5. Critical and multiple microphone placement
6. Operational complexities.

The size and dimensions of the studio comprise a certain problem in studio design since an optimum volume per musician in the studio exists. Reduced to practice, however, this problem becomes one of



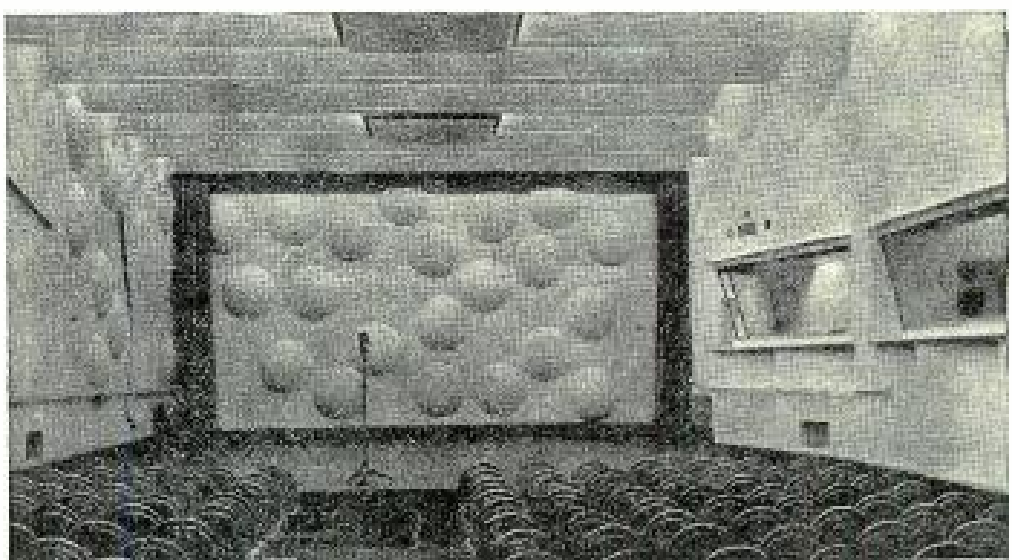
Courtesy Johns Manville Corp.

Fig. 19-4. The absorption by the air of high-frequency sound waves varies with the frequency and the distance from the source.

simply proportioning the studio for a certain maximum number of musicians expected. This is possible because no difficulty exists in obtaining a good pickup of a smaller group in a studio designed for a greater number of musicians; whereas, due to the fact that a small room cannot conveniently be "aurally" enlarged, a large band in a small studio presents a difficult problem. Portable hard "flats" are often used in large studios to enclose a small group of musicians, thus providing the optimum dimensions required for good pickup of a given number of performers.

High-frequency absorption, particularly frequencies of over 5000 cycles, is relatively great as indicated in Fig. 19-4. The absorption of sound by air at these frequencies is actually greater than the surface absorptivity of the studio even under normal temperature and relative humidity conditions. It is not possible to construct a studio having a reverberation time of over 1.2 seconds at 10,000 cycles even with theoretical zero absorptivity in acoustical treatment.[1] This, then, makes obvious the fact brought out before concerning optimum volume per musician in studio design. By distributing the reflector surfaces in proximity to the musical instruments, a maximum of diffused, polyphased high-frequency sound will exist at the microphone without being attenuated injuriously by space in back of the instruments. A minimum number of microphones for adequate pickup is necessary under these conditions.

In general, modern studios are of two types. First is the live-end, dead-end type in which the talent is placed in the live-end and microphones placed in the "microphone area" in the dead-end, thus achieving the correct reverberation of sound waves striking the microphone without bothersome reflections from side and rear walls. This type of studio, as shown in Fig. 19-5, has the advantage of retaining a defi-



NBC Photo

Fig. 19-5. An example of a live-end, dead-end studio.

[1] M. Rettinger, "Acoustics in Studios," *Proc.* IRE, July, 1940.

nite reverberation time not influenced by the size of the studio audience in the dead-end of the studio. It has the disadvantage of limiting the pickup to a definite area in the studio. Second is the general-purpose type studio, consisting of uniformly distributed acoustic treatment, or panels of different type of acoustical elements to achieve a desired condition.

Fig. 19-6 shows graphically the sound-absorbing characteristics of three materials developed by the research department of Johns-Manville in their acoustical laboratory. By proportioning the amount or adjusting the orientation of these three materials in a studio, the time-frequency curve will achieve any desired contour. This type of studio

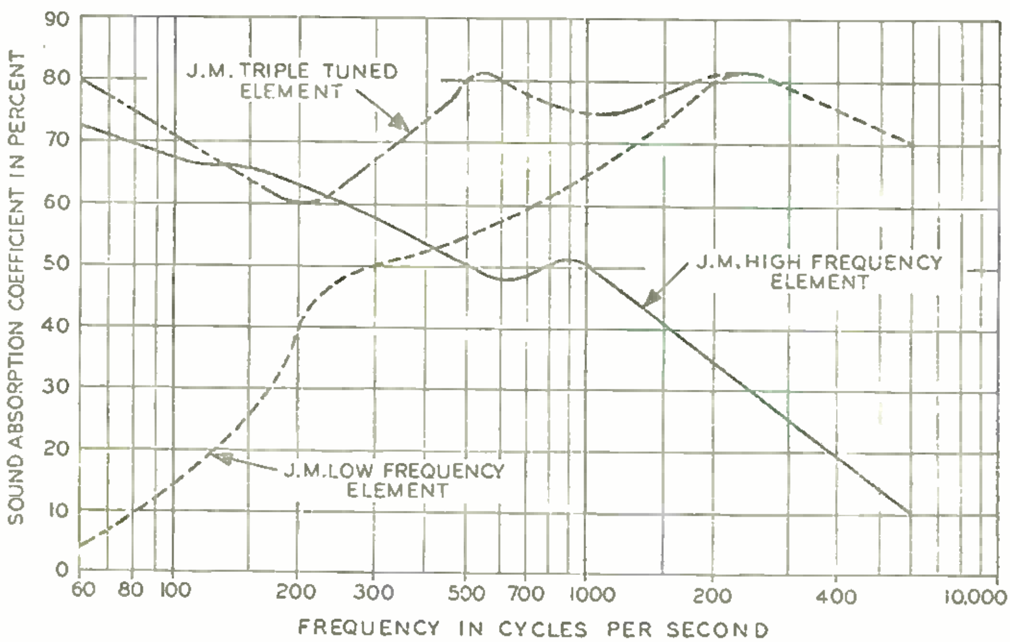


Fig. 19-6, above. The sound absorbing characteristics of three acoustical materials.

Courtesy Johns Manville Corp.

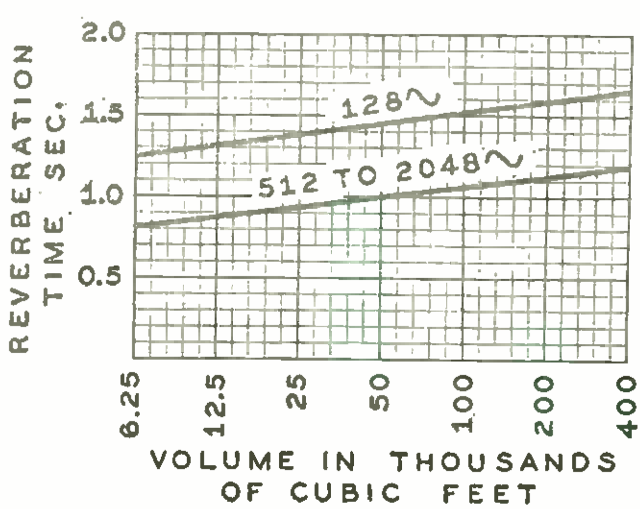


Fig. 19-7, right. Optimum reverberation time for studios of various sizes.

After Knudsen

has the advantage of unlimited pickup area, but has the disadvantage of being affected by size of the studio audience, since a great difference exists in reverberation time when the studio is vacant and when it is occupied by a large group of performers and a large studio audience. Optimum studio reverberation time is shown in the graph of Fig. 19-7.

Chapter 20

SELECTING THE BROADCAST TRANSMITTER LOCATION

CHOICE of the broadcast transmitter site is a highly specialized field that usually comes under the supervision of a consulting engineering firm. A brief outline of the factors affecting the proper location, however, is of prime importance to the serious broadcast employee who likes to have a comprehensive picture of operation and engineering.

In the discussion to follow, it is necessary to keep in mind that field-strength of a radio wave is expressed in "millivolts" or "microvolts per meter." This is a measurement of the stress produced in the ether by the carrier wave that is equivalent to the voltage induced in a conductor one meter in length due to the magnetic flux of the wave sweeping across the conductor at the velocity of light. This field strength is greatly affected by the conductivity of the soil over which it travels. The soil conductivity is expressed in "electromagnetic units," abbreviated emu. This value of soil conductivity varies over a considerable range with the type of soil concerned. Values will be around 3×10^{-13} emu for most loam (good conductivity) and about 1×10^{-14} emu for dry, sandy, or rocky ground which has relatively poor conductivity.

Service Area

The "primary coverage area" of a broadcast transmitter is that area around the towers which provides a distortionless and interference-free signal. This is provided by the ground wave, which must have a carrer-to-noise ratio of at least 18 db, and a field strength of at least several times the strength of the sky wave at the point measured.

The so-called "secondary coverage area" is that area outside the primary area which is supplied primarily by the sky wave. The sky wave, of course, is subject to selective fading (due to changing heights of the Heaviside layer) with resulting distortion effects. The sky wave at broadcast frequencies is almost completely absorbed in the daytime, thus a secondary service area of any appreciable extent appears only at night. Fig. 20-1 shows how the attenuation of the sky wave varies through the sunset period.

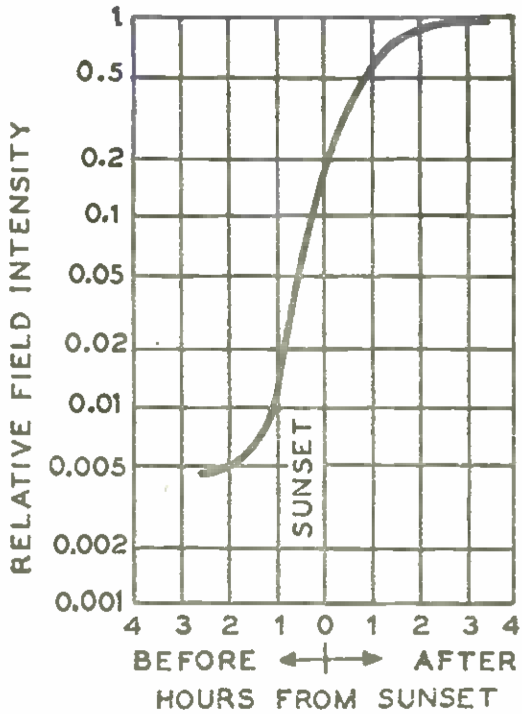


Fig. 20-1. The relative field intensity increases sharply after sunset. Measurements taken at 800 kc over 560 miles during spring.

After FCC

Required Field Strength

Since the required field strength for satisfactory coverage depends on the existing interference level, the value will vary with location. It may be assumed in general that the interference level is greatest in the industrial and business sections of metropolitan areas, less in the residential areas, and still less in rural areas.

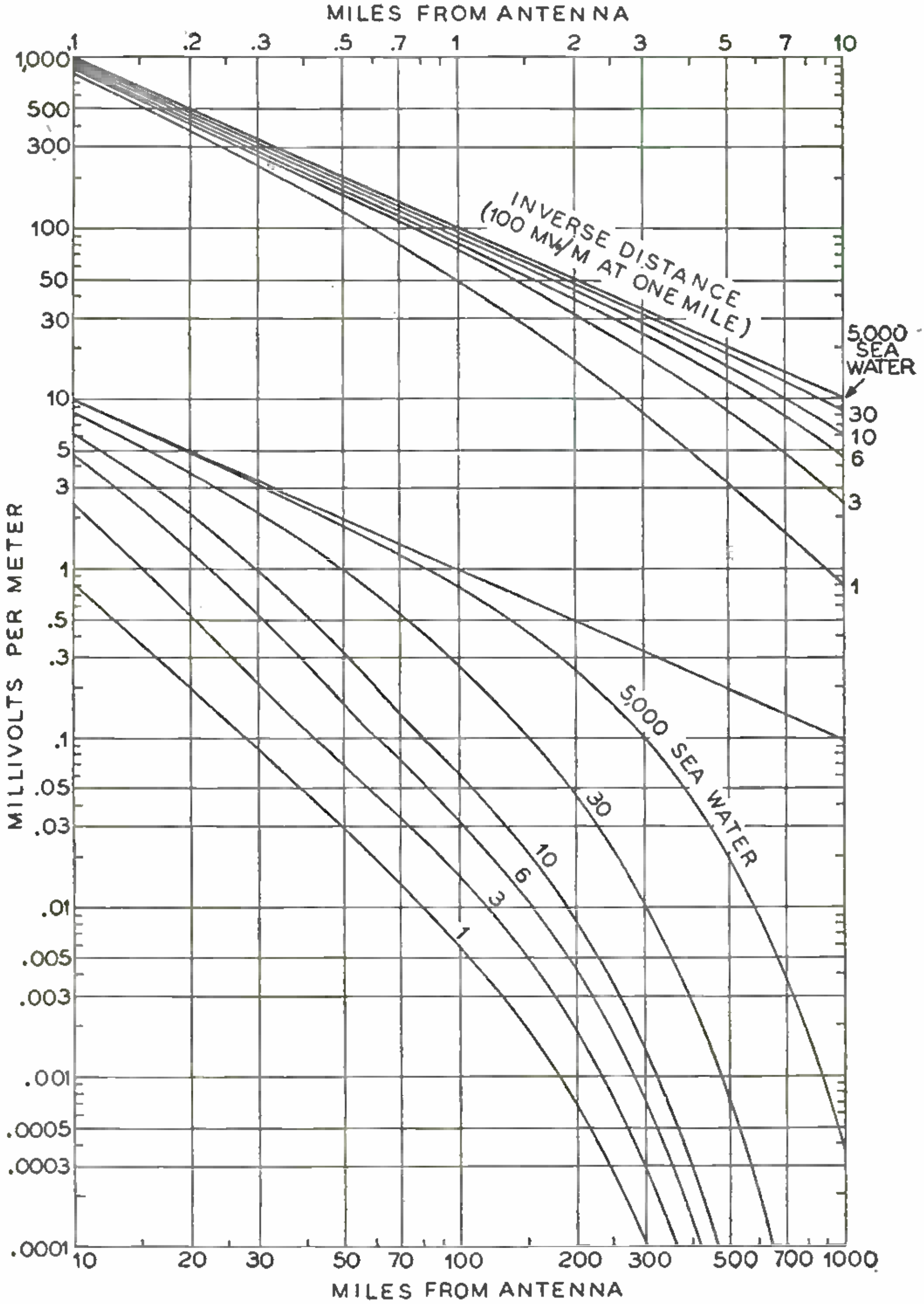
TABLE 1

PRIMARY SERVICE

Area:	Field Intensity Ground-Wave
City business or factory areas	10 to 50 mv/m
City residential areas	2 to 10 mv/m
Rural—all areas during winter or northern areas during summer	0.1 to 0.5 mv/m
Rural—southern areas during summer	0.25 to 1.0 mv/m

—From FCC Standards

Table 1 shows the approxmate field strengths necessary to render adequate service (for primary area) under various conditions. In some locations where conditions are more favorable than average, primary service may be obtained with somewhat weaker field strength than those indicated, and, of course, coverage of an intermittent na-



After FCC

Fig. 20-2. The conductivity of the soil has a great effect on the attenuation of the broadcast signal.

TABLE 2

PROTECTED SERVICE CONTOURS AND PERMISSIBLE INTERFERENCE SIGNALS FOR BROADCAST STATIONS

Class of Station	Class of Channel Used	Permissible Power	Signal Intensity Contour of Area Protected From Objectionable Interference[1]		Permissible Interfering Signal on Same Channel[2]	
			Day[3]	Night	Day[3]	Night[4]
Ia......	Clear	50 kw	SC 100 uv/m AC 500 uv/m	Not duplicated	5 uv/m	Not duplicated
Ib......	Clear	10 kw to 50 kw	SC 100 uv/m AC 500 uv/m	500 uv/m (50% sky wave)	5 uv/m	25 uv/m
II......	Clear	0.25 kw to 50 kw	500 uv/m	2500 uv/m[5] (ground wave)	25 uv/m	125 uv/m[5]
III–A ..	Regional	1 kw to 5 kw	500 uv/m	2500 uv/m (ground wave)	25 uv/m	125 uv/m
III–B ..	Regional	0.5 to 1 kw night and 5 kw day	500 uv/m	4000 uv/m (ground wave)	25 uv/m	200 uv/m
IV.....	Local[6]	0.1 kw to 0.25 kw	500 uv/m	400 uv/m (ground wave)	25 uv/m	200 uv/m

[1] When it is shown that primary service is rendered by any of the above classes of stations, beyond the normally protected contour, and when primary service to approximately 90 per cent of the population (population served with adequate signal) of the area between the normally protected contour and the contour to which such station actually serves, is not supplied by any other station or stations, the contour to which protection may be afforded in such cases will be determined from the individual merits of the case under consideration. When a station is already limited by interference from other stations to a contour of higher value than that normally protected for its class, this contour shall be the established standard for such station with respect to interference from all other stations.

[2] For adjacent channels see Table 3.

[3] Ground wave.

[4] Sky wave field intensity for 10 percent or more of the time.

[5] These values are with respect to interference from all stations except Class Ib, which stations may cause interference to a field intensity contour of higher value. However, it is recommended that Class II stations be so located that the interference received from Class Ib stations will not exceed these values. If the Class II stations are limited by Class Ib stations to higher values, then such values shall be the established standard with respect to protection from all other stations.

[6] Class IV stations may also be assigned to regional channels according to section 3.29.

SC = Same channel.

AC = Adjacent channel.

ture prevails at times in localities where an hour-to-hour variation of interference intensity occurs.

Approval of a transmitter site by the FCC must entail an application which includes a map showing the 250-, 25-, and 5-mv/m contours and the population residing in the 250-mv/m contour (the so-called "blanket area"). This map also indicates by symbols the character of each area (business, manufacturing, residential, etc.), heights of tallest buildings or other obstructions, density and distribution of population, and location of airports and airways. The field-strength contours which would be produced by a transmitter at any particular location, the population within each contour, and the areas where the signal might be subject to nighttime fading and interference, are the determining factors in choosing the most favorable site. For this reason, propagation data that permit prediction of signal attenuation in all directions from a proposed location are of prime importance to the engineer.

TABLE 3

ADJACENT CHANNEL INTERFERENCE

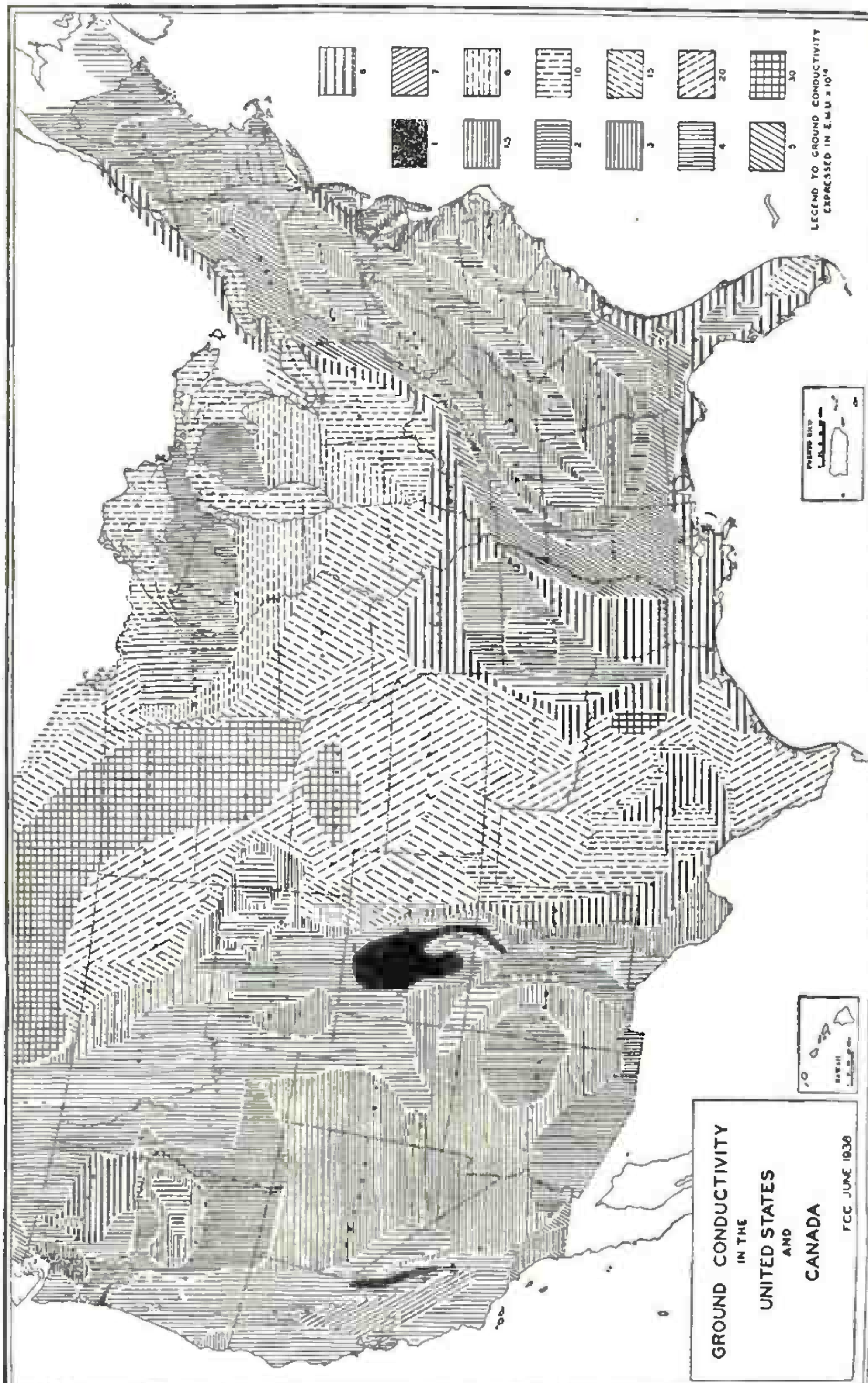
	Maximum Ground Wave Field Intensity of Undesired Station
Channel separation between desired and undesired stations:	
10 kc.	0.25 mv/m
20 kc.	5.0 mv/m
30 kc.	25.0 mv/m

—From FCC Standards

Ground Wave Propagation Data

The primary service area resulting from a transmitter of given frequency and power depends upon earth conductivity and directivity of the antenna system. The graph of Fig. 20-2 illustrates the effect of soil conductivity on signal attenuation. This type of graph is published by the FCC in blocks of frequencies as shown, some 20 graphs being required to cover the broadcast-band assignments. They show the ground-wave field intensity curve plotted against distance for various conductivity values.

Fig. 20-3 is a map of the approximate and average soil conductivity values for the United States. The protected service contours and permissible interference signals on the same channel for various classes



Courtesy FCC

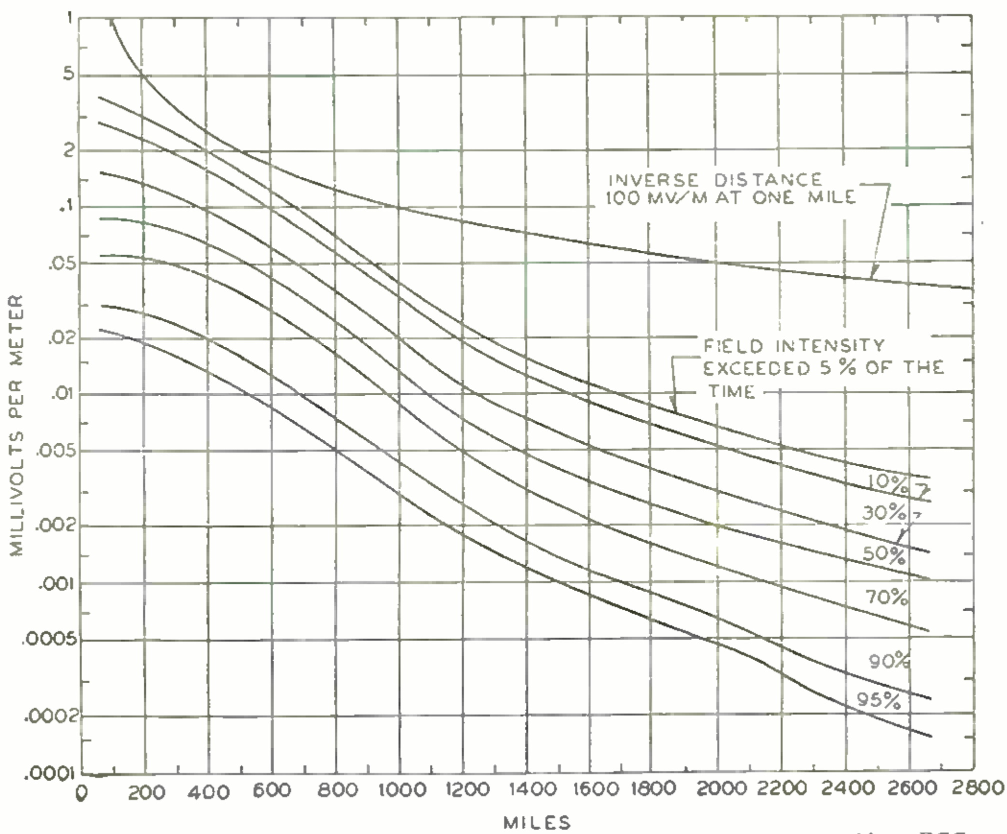
Fig. 20-3. The approximate and average soil conductivity values for the United States.

of broadcast stations are shown in Table 2. Permissible interference levels for adjacent channels is shown in Table 3.

The above curves and tables form the nucleus for gaining necessary information concerning the proposed transmitter site as follows:

Using the Propagation Data

Assume that it is desired to locate a 5-kw class 2 station on 980 kc, 175 miles from a class 2 station of 1-kw power on 990 kc. It is necessary to determine the amount of interference caused by the proposed station to the established 1-kw 990-kc transmitter. Assume also that both stations use nondirectional antennas of such height as to produce an effective field (for 1 kw) of 175 mv/m. Assume further that they are located so that observation of the map of Fig. 20-3 shows an estimated ground conductivity of 6 x 10^{-14} emu. Looking up the required protection to class II during the daytime in Table 2, it may be seen that the protection is to the 500 μv/m contour. The curves of Fig. 20-2 are plotted for 100 mv/m at a mile; therefore, to find the



After FCC

Fig. 20-4. Average sky-wave field intensity, corresponding to the second hour after sunset at the recording station.

distance to the 500 μv/m contour of the 1-kw station we must determine the distance on the appropriate curve to the

$$\frac{100 \times 500}{175} = 285$$

285 μv/m contour. Now, by using the graph of Fig. 20-2 and the curve marked 6 (for 6 x 10^{-14} emu) it is found that the service area (estimated) of the 1-kw station is about 40 miles. Since $175 - 40 = 135$, we have 135 miles for the interfering signal of the 5-kw station to travel. Again using the appropriate curve of Fig. 20-2, it is found that the signal from the 5-kw station at 135 miles would be 62.5 μv/m. Since the stations are separated by 10 kc, the interfering signal may have a value up to 250 μv/m allowable by the FCC, as shown in Table 3.

The principles as outlined above are not used when the sky wave of the interfering station is in excess of 5 times the established signal for 10% or more of the time (with frequency separation of 10 kc). When this condition prevails, the interference must be estimated on the basis of the sky wave also, and the propagation curve of Fig. 20-4 for sky wave signals must be considered.

Other Factors

Other considerations than effective conductivity of the area surrounding the proposed site must be taken into account. Following are excerpts from the FCC Standards of Good Engineering Practice which outline these extra factors:

As a guide, the Engineering Department has established certain engineering principles based on the extensive experience of the Engineering Department and all data available along this line, including those presented at the informal engineering hearings of October 5, 1936, January 18, 1937, and June 6, 1938.

The four primary objectives to be obtained in the selection of a site for a transmitter of a broadcast station are as follows:

1. To serve adequately the center of population in which the studio is located and to give maximum coverage to adjacent areas.
2. To cause and experience minimum interference to and from other stations.

3. To present a minimum hazard to air navigation consistent with objectives 1 and 2.
4. To fulfill certain other requirements given below.

TABLE A

Power of Station	Population of City or Metropolitan Area[1]	Approximate Radius of Blanket Area 250 mv/m[2]	Site—Distance From Center of City (Business or Geographical)	Maximum Percentage of Total Population in Blanket Area[1]
		Miles	*Miles*	*Percent*
100 watts	5,000–50,000	0.15	½–1	1
100 watts	50,000 or more	0.15	([3])	...
250–500 watts	5,000–150,000	0.3–0.5	1–3	1
250–500 watts	150,000 or more	0.3–0.5	([3])	...
1 kilowatt	5,000 to 200,000	0.6–0.9	2–5	1
1 kilowatt	200,000 or more	0.6–0.9	([3])	...
5–10 kilowatts	All	1.5–2.5	5–10	1
25–50 kilowatts	All	3.0–4.5	10–15	1

[1] The total population is the population of the city sought to be served except in those instances when the station is to be located in an area classified by the Department of Commerce, Bureau of Census, as a metropolitan area, in which case the population of the metropolitan area shall apply: *Provided, however*, That when the power of the station is such that all the metropolitan area cannot be served, the population that will actually be served shall determine. The population figures are those determined by the latest official census and where greater population is claimed, the burden of proof is on the applicant.

[2] These radii are only approximate and the actual blanket area (area within the 250 mv/m contour) may be materially different depending on the antenna employed and other factors.

[3] In these instances it is usually necessary to locate the station within the city in order to render satisfactory service throughout the city. Such sites shall be in or near the center of the business district and under no circumstances will a site in the residential area be approved.

—From FCC Standards

Table A is offered as a general guide to be used in determining the approximate site of broadcast transmitters.

In case the power and the population of the city are such that it should be located at some distance from the center of the city, the approximate distance is given as well as the population of the so-called "blanket area." The "blanket area" of a broadcast station is defined as that area adjacent to the transmitter in which the usual broadcast receiver would be subject to some type of interference to the reception of other stations due to the strong signal from the station. The normal blanket area of a broadcast station is that area lying within the 250-millivolt-per-meter contour line. The average radii of the blanket areas for broadcast stations of the various powers are given in Table A.

In those cases where it is impossible or impractical to locate a station in accordance with the above specifications, the Commission will give consideration to approving locations where not more than 1% of the population (as above specified) is included within the 500-millivolt-per-meter contour, provided the applicant submits an affidavit setting forth the reasons why the normal specifications cannot be complied with, and further that the applicant will assume full responsibility for adjustment of any reasonable complaints arising from the excessively strong signals of the applicant's station. Particular attention must be given to avoiding cross modulation.

In this connection, attention is invited to the fact that it has been found very unsatisfactory to locate broadcast stations so that high signal intensities occur in areas with overhead electric power or telephone distribution systems and sections where the wiring and plumbing are old or improperly installed. These areas are usually found in the older or poorer sections of a city. These conditions give rise to cross-modulation interference due to the nonlinear conductivity characteristics of contacts between wiring, plumbing, or other conductors. This type of interference is independent of the selectivity characteristics of the receiver and normally can be eliminated only by correction of the condition causing the interference. Cross modulation tends to increase with frequency and in some areas it has been found impossible to eliminate all sources of cross modulation, resulting in an unsatisfactory condition for both licensee and listeners.

Broadcast station transmitters will not be permitted to be located in these areas even though the population is within the requirements of Table A, unless the licensee assumes full responsibility for, and it appears it can adjust all complaints satisfactorily.

If the city under consideration is of irregular shape, the station is of high power, a directional antenna system is employed, or if other unusual conditions obtain, the table may not apply and special consideration must be given. However, the general principles set out will still apply.

In selecting a site in the center of a city it is usually necessary to place the radiating system on the top of a building. This building should be large enough to permit the installation of a satisfactory ground and/or counterpoise system. Great care must be taken to avoid selecting a building surrounded by taller buildings or where any near-by building higher than the antenna is located in the direction which it is desired to serve. Such a building will tend to cast "radio shadows," which may materially reduce the coverage of the station in that direction. Irrespective of the height of surrounding buildings, the building where the antenna is located should not have a height of approximately one-quarter wavelength. A study of antenna systems located on buildings tends to indicate that where the building is approximately a quarter wavelength in height, the efficiency of radiation may be materially reduced.

TABLE B

Type of Terrain	Inductivity	Conductivity	Absorption Factor at 50 Miles 1000 kc[1]
Sea water, minimum attenuation	81	4.64×10^{-11}	1.0
Pastoral, low hills, rich soil, typical of Dallas, Tex., Lincoln, Nebr., and Wolf Point, Mont., areas	20	3×10^{-13}	0.50
Pastoral, low hills, rich soil, typical of Ohio and Illinois	14	10^{-13}	0.17
Flat country, marshy, densely wooded, typical of Louisiana near Mississippi River	12	7.5×10^{-14}	0.13
Pastoral, medium hills, and forestation, typical of Maryland, Pennsylvania, New York, exclusive of mountainous territory and sea coasts	13	6×10^{-14}	0.09
Pastoral, medium hills, and forestation, heavy clay soil, typical of central Virginia	13	4×10^{-14}	0.05
Rocky soil, steep hills, typical of New England	14	2×10^{-14}	0.025
Sandy, dry, flat, typical of coastal country	10	2×10^{-14}	0.024
City, industrial areas, average attenuation	5	10^{-14}	0.011
City, industrial areas, maximum attenuation	3	10^{-15}	0.003

[1] This figure is stated for comparison purposes in order to indicate at a glance which values of conductivity and inductivity represent the higher absorption. This figure is the ratio between field intensity obtained with the soil constants given and with no absorption.

—From FCC Standards

If from Table A it is determined that a site should be selected removed from the city, there are several general conditions to be followed in determining the exact site. The table gives the approximate distance from the center of the city. Three maps should be given consideration if available:

1. Map of the density of population and number of people by sections in the area.
2. Geographical contour map with contour intervals of 20 to 50 feet.
3. Map showing the type, nature, and depth of the soil in the area with special reference to the condition of the moisture throughout the year. (See Table B.)

From these maps a site should be selected that is approximately the required distance from the city, with a minimum population in the "blanket area," and with a minimum number of intervening hills between it and the center of the city. In general, because of ground conditions, it is better to select a site in a low area rather than on top of a hill, and the only condition under which a site on top of a hill should be selected is that only by this means is it possible to avoid a substantial number of hills between the site and the center of a city with the resulting radio shadows. If a site is to be selected to serve a city which is on a general sloping area, it is generally better to select a site below the city than above the city.

If a compromise must be made between probable radio shadows from intervening hills and locating the transmitter on top of a hill, it is generally better to compromise in favor of the low area, where an efficient radiating system may be installed which will more than compensate for losses due to shadows being caused by the hills if not too numerous or too high. Several transmitters have been located on top of hills, but as far as data have been supplied, not a single installation has given superior efficiency of propagation and coverage.

The ideal location of a broadcast transmitter is in a low area of marshy or "crawfishy" soil or area, which is damp the maximum percentage of time and from which a clear view over the entire center of population may be had and the shadow of the tall buildings in the business section of the city would be cast across the minimum residential area.

The type and condition of the soil or earth immediately around a site is very important. Important, to an equal extent, is the soil or earth between the site and the principal area to be served. Sandy soil is considered the worst type, with glacial deposits and mineral-ore areas next. Alluvial, marshy areas, and salt-water bogs have been found to have the least absorption of the signal. One is fortunate to have available such an area and, if not available, the next best condition must be selected.

Table B indicates the values of inductivity and conductivity which it is recommended be used for various types of country in the absence of surveys over the particular area involved. Naturally, values obtained from the use of these figures will be only approximate and should, if possible, be replaced by actual measurements in the area under consideration.

Careful consideration must be given to selecting a site so that the number of people in the blanket area is a minimum. The last column of Table A gives the percentage of the total population of the city or metropolitan area that may be permitted in the blanket area. In general, broadcast transmitters operating with approximately the same power can be grouped in the same approximate area and thereby reduce the interference between them.

If the city is of irregular shape, it is often possible to take advantage of this in selecting a suitable location that will give a maximum coverage and at the same time maintain a minimum of people within the blanket area. The maps giving the density of population will be a key to this. The map giving the elevation by contours will be a key to the obstructing hills between the site and city. The map of the soil conditions will assist in determining the efficiency of the radiating system that may be erected and the absorption of the signal encountered in the surrounding area.

Another factor to be considered is the relation of the site to airports and airways. There are no regulations or laws with respect to distance from airports and airways, but a distance of 3 miles from each is used as a guide. In case a suitable location is found at less distance than this, it may be satisfactory if the towers are suitably painted and lighted in conformity with the requirements of the Civil Aeronautics Administration, or if the towers are not higher than the surrounding objects. The latter is normally considered poor engineering practice; however, in selecting a site the local aeronautical authorities should always be consulted if there is any question concerning erecting a hazard to aviation, and in case of towers over 200 feet high this should always be done. In passing on a location and antenna installation, the Engineering Department refers each case to the Civil Aeronautics Administration for its recommendation. The action of the Administration will be materially expedited by the district airline inspector and local representatives of the airports and airlines forwarding their approval or comments to the Civil Aeronautics Administration, Washington, D. C.

In finally selecting the site, consideration must be given to the required space for erecting an efficient radiating system, including the ground or counterpoise. It is the general practice to use direct grounds consisting of a radial buried-wire system. If the area is such that it is not possible to get such a ground system in soil that remains moist throughout the year, it probably will be found better to erect a counterpoise. (Such a site should be selected only as a last resort.) It, like the antenna itself, must of course be designed properly for the operating frequency and other local conditions.

While an experienced engineer can sometimes select a satisfactory site for a 100-watt station by inspection, it is necessary for engineers of a higher power station to make a field-intensity survey to determine that the site selected will be entirely satisfactory. There are several facts that cannot be determined by inspection that make a survey very desirable for all locations removed from the city. Often two or more sites may be selected that appear to be of equal promise. It is only by means of field-intensity surveys taken with a transmitter at the different sites or from measurements on the signal of near-by stations traversing the terrain involved, that the most desirable site can be determined. There are many factors regarding site efficiency that cannot be determined by any other method.

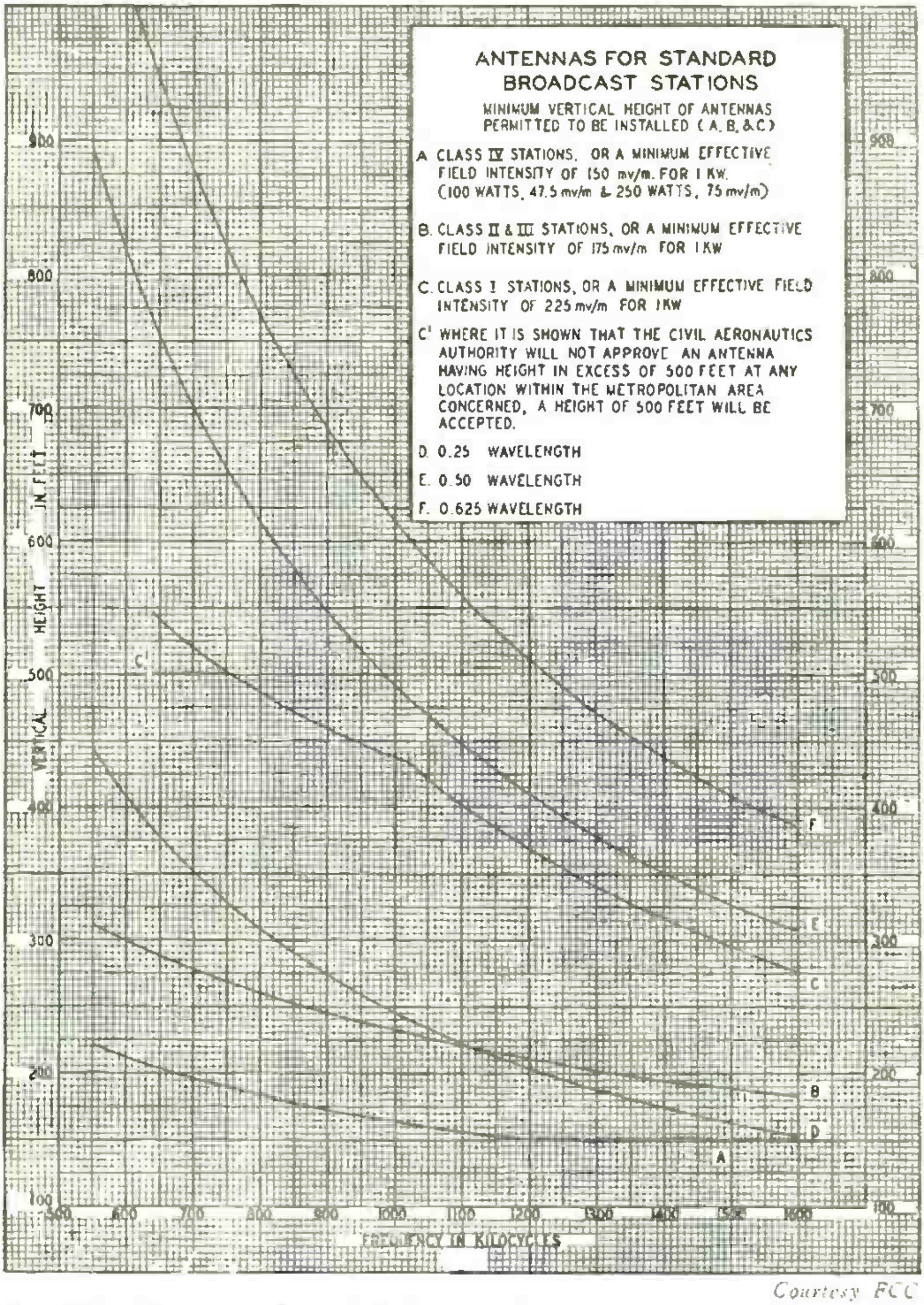
The site selected should meet the following conditions:

1. A minimum field intensity of 25 to 50 millivolts per meter will be obtained over the business or factory areas of the city.
2. A minimum field intensity of 5 to 10 millivolts per meter will be obtained over the most distant residential section.
3. The absorption of the signal is the minimum for any obtainable sites in the area. As a guide in this respect the absorption of the signals from other stations in that area should be followed, as well as the results of tests on other sites.
4. The population within the blanket radius (250 mv/m) does not exceed that specified by Table A.

When making the final selection of a site, the need for a field-intensity survey to establish the exact conditions cannot be stressed too strongly. The selection of a proper site for a broadcast station is an important engineering problem and can only be done properly by experienced radio engineers.

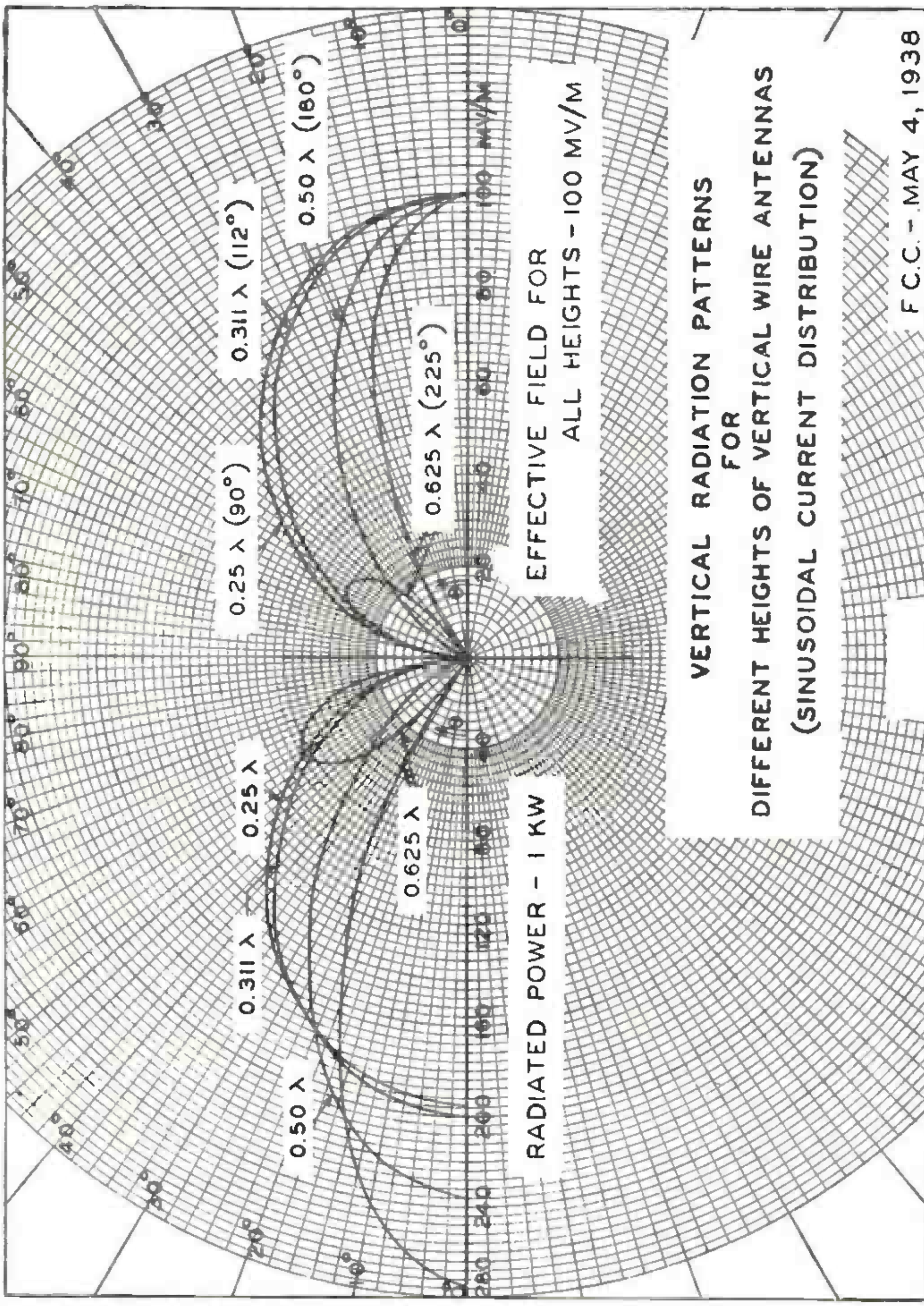
BROADCAST ANTENNA SYSTEMS

As was pointed out in the previous discussion of transmitter location problems, the efficiency of service depends principally upon four



Courtesy FCC

Fig. 20-5. Curves A, B, and C show minimum antenna height needed to deliver the required field intensity for different class stations. Curves D, E, and F show antenna heights for fractions of wavelengths between 500 to 1600 kc.



Courtesy FCC

Fig. 20-6. Comparative vertical radiation patterns for antennas of 0.25, 0.311, 0.5, and 0.625 wavelengths.

factors: frequency of operaton, operating power, ground conductivity, and orientation of transmitter with respect to distribution of population. A fifth factor, namely the design of the radiating system, will also affect the over-all efficiency, especially in areas at a distance from the particular transmitter site.

When application is made to the FCC for new, additional, or modified broadcast facilities (such as changing transmitter location), the applicant must specify the nature of the radiating system to be employed. This system must comply with efficiency standards adopted by the FCC to meet the requirements of good engineering practice for the particular class of service concerned.

To this end, the FCC has set up standards which specify a minimum effective field intensity for any particular class of station. Fig. 20-5, curves A, B, and C show the minimum actual physical height of antennas deemed necessary to deliver the required field intensity for the class station involved.

Observation of these curves show the following requirements:

Curve A. Class IV stations, a minimum height of 150 feet (for frequencies 1200 kc and higher) or a minimum effective field intensity of 150 mv/m for 1 kilowatt (100 watts 47.5 mv/m and 250 watts, 75 mv/m).

Curve B. Class II and III stations. Minimum effective field intensity of 175 mv/m for 1 kilowatt.

Curve C. Class I stations. Minimum effective field intensity of 225 mv/m for 1 kilowatt.

Curves D, E, and F show the physical heights of the antenna for 0.25, 0.5, and 0.625 wavelengths for any frequency from 500 to 1600 kc.

Considerations in Antenna System Design

Some interesting points are involved in the design applications of radiating systems for broadcast frequencies. Fig. 20-6 illustrates the comparative vertical radiation patterns for antennas of 0.25, 0.311, 0.5, and 0.625 wavelengths. Observation of this figure reveals that although an antenna of 0.625 wavelength has a large low-angle lobe, a secondary lobe exists at a higher angle which decreases the effective fade-free area. Fading occurs when the sky wave caused by the reflected energy meets the ground wave and tends to cancel out the signal due to phase reversal.

It has been found in practice, for example, that the strength of the ground wave at a given distance is increased only a few decibels by increasing the height of the antenna from 0.125 to 0.5 wavelength, but the *effective* fade-free area is greatly increased due to the reduction in strength of the high-angle radiation producing a sky wave that returns to ground close to the transmitting location. Increased directivity in the horizontal plane is the main purpose of using higher physical wavelengths over a quarter wavelength antenna. It has been found that an antenna of 190° or 0.53 wavelength is the most efficient height to use where cost of such installation is warranted by conditions involved.

An adequate ground system must be employed with the broadcast antenna in order to obtain maximum efficiency. The FCC specifies that where the vertical radiator is used with the base on the ground, a ground system must be employed consisting of buried radial wires at least one-quarter wavelength long. They require at least 90 such radials, and recommend 120 radials of 0.35 to 0.4 wavelength spaced 3°. In case of high base voltage (such as occurs in antennas approaching 0.5 wavelength) a base screen of adequate dimensions should be employed to prevent high dielectric losses.

Outline of Transmitter Installations

Modern broadcast transmitters come in sections with nearly all the parts already mounted in place. Terminal boards with numbered connections are used to provide connection to the power lines and inter-unit connections, with wires run in raceways behind the units or in the wiring channel along the elevated back base. Manufacturers always furnish detailed blueprints and pictures showing wire connections to each number on each unit and recommended wire size.

Audio-frequency wires should be installed with twisted pair, leaded covered wire, and audio grounds should be separate from power line and r-f grounds. These precautions help to prevent background noise in audio circuits which would result from voltage drops along common ground wires carrying power and r-f ground currents. Audio line terminations, pads, equalizers, line amplifiers, and measuring equipment, such as frequency monitors, modulation monitors, etc., are placed in a rack apart from the regular transmitter, with power supply and audio circuit wiring run in conduits and terminated at the base of the equipment.

Before final testing can take place in a completed broadcast installation, it is necessary that a dummy antenna of the required impedance and power dissipation rating be available, or that the transmission lines and antenna circuits be properly adjusted so that the power amplifier will work into its intended load.

Antenna Tuning

It is well known that the impedance of an antenna follows conventional transmission-line theory and does not vary with frequency as does the impedance of an ordinary tuned circuit. The reactive component of the antenna impedance varies rapidly from capacitive to inductive at each quarter wavelength point and antennas of near these values in electrical height of the operating frequency must have accurate impedance measurements made so that tuning and feeding methods may be devised. The reactance of the antenna must be determined since the tuning reactance required to bring the system to resonance at the operating frequency must be equal to that value in magnitude, but opposite in sign. The resistive component must be determined in order to devise the coupling circuit necessary to match the transmission line to the antenna.

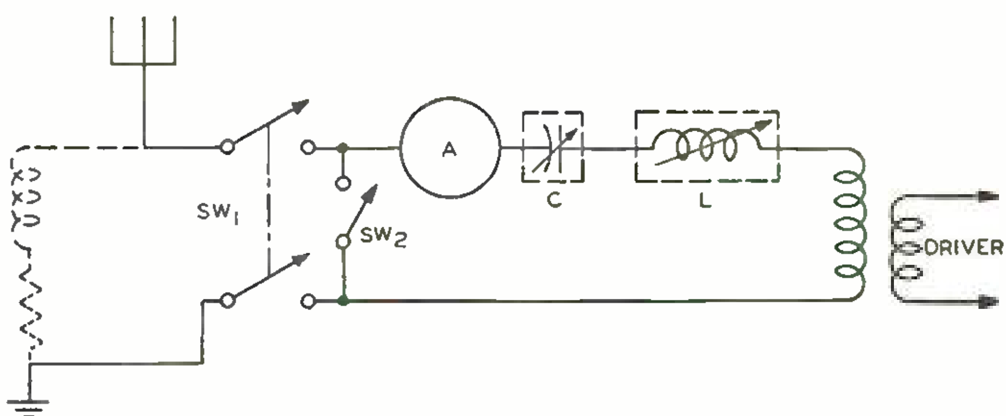


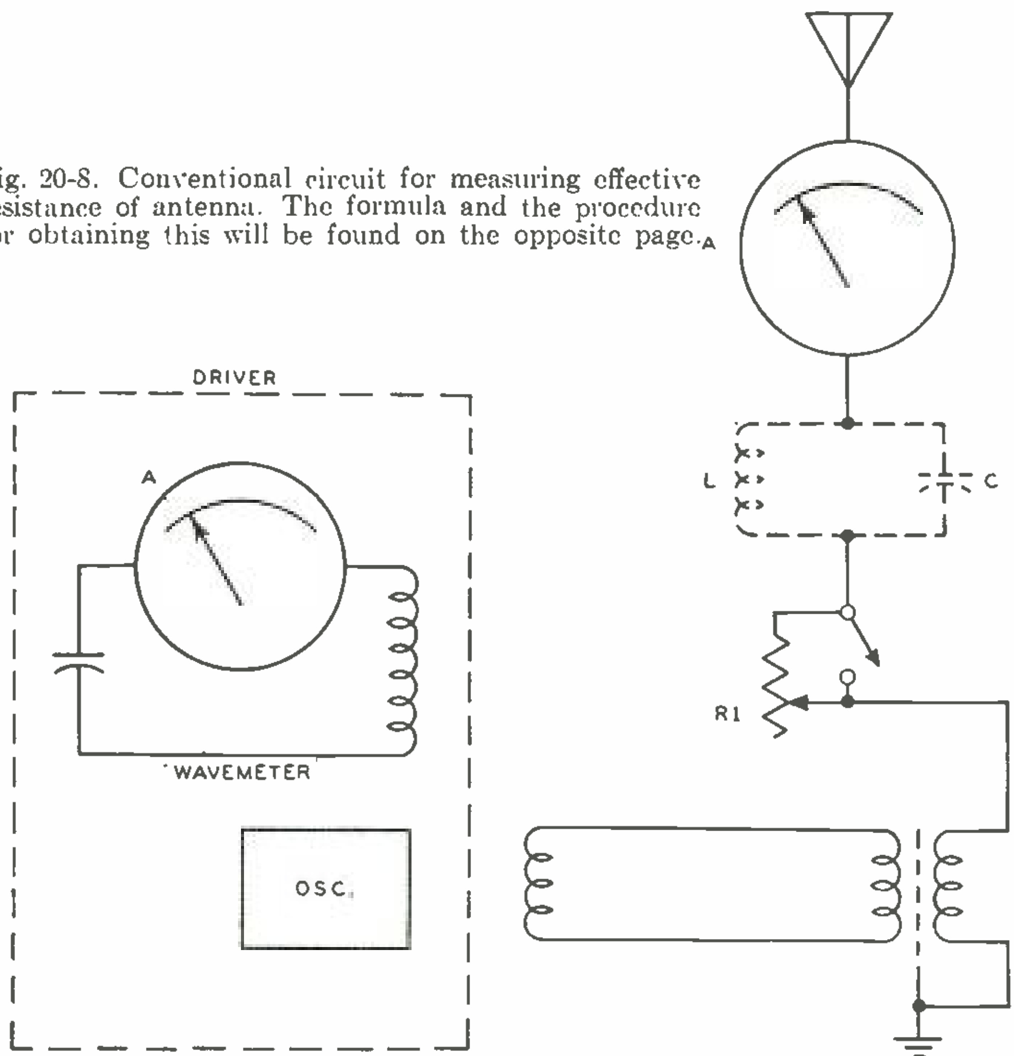
Fig. 20-7. Schematic of apparatus used in one procedure of measuring antenna reactance.

One method of determining antenna reactance is shown in Fig. 20-7. An oscillator tuned to the desired frequency is used to excite the variable inductance *L* and the calibrated variable capacitor *C* in the arrangement as illustrated. Closing switch *SW1* connects the antenna termination with the measuring elements. With the oscillator tuned to resonance at the operating frequency as determined by minimum plate-current indication of the oscillator tube (unity power factor), the calibrated capacitor *C* is varied to the point of maximum indication of the ammeter *A*, indicating that the reactance of the entire circuit has been canceled. The capacitance at this point is noted from the calibration and the capacitive reactance of the capacitor determined for the operating frequency as:

$$X_c = \frac{10}{2\pi fc}\text{ ohms}$$

SW1 is then opened and *SW2* closed. The capacitor is again varied until the series circuit is in resonance as again indicated by the ammeter. The new capacitive value is used to determine the reactance as before. The difference between these two reactance values will be the effective antenna reactance. The sign of the reactance is determined by noting in which direction the capacitor was varied for the latter operation to bring about resonance. If the capacitance was increased,

Fig. 20-8. Conventional circuit for measuring effective resistance of antenna. The formula and the procedure for obtaining this will be found on the opposite page.



the antenna reactance is negative (-j) and a coil must be used to tune the antenna system to resonance.

The resistive component of antenna impedance includes dielectric losses, eddy-current losses in near-by objects, and radiation resistance. The conventional circuit for measuring effective antenna resistance is shown in Fig. 20-8, and the formula is:

$$R_A = \frac{I_l}{I - I_l} R_l$$

where R_A = antenna resistance

I = antenna current with the known resistance R_l short circuited

I_l = antenna current with R_l in the circuit.

The procedure is as follows: the antenna circuit is adjusted to resonance by means of the capacitor C or inductance L, depending on the reactance of the antenna as outlined earlier. The short-circuiting switch is closed to remove R_l (the known resistance), and the reading noted on the r-f milliammeter. This is I in the above formula. The switch is then opened and a small value of the calibrated resistor inserted. This will result in a new reading I_l in the formula. The antenna resistance R_A is then calculated as shown. It is usual practice to take meter readings at 5 or 6 different values of inserted resistance and average the results.

Circuit Tests

High power should not be applied to the transmission line until the coupling and tuning units have been adjusted to the correct characteristics by means of the oscillator as just described. High power applied to a transmission line that may be out of correct adjustment is apt to cause high standing waves on the line causing arc-overs, especially in closely spaced elements of a concentric line. When the proper impedance matching has been achieved, low power is applied to the line, and a final check made on the antenna installation by inserting an ammeter in series with each end of the transmission line. It is usually considered a satisfactory adjustment if the two meters show an indication within 20% of the value of the following formula:

$$I_L = \sqrt{\frac{W}{Z_o}}$$

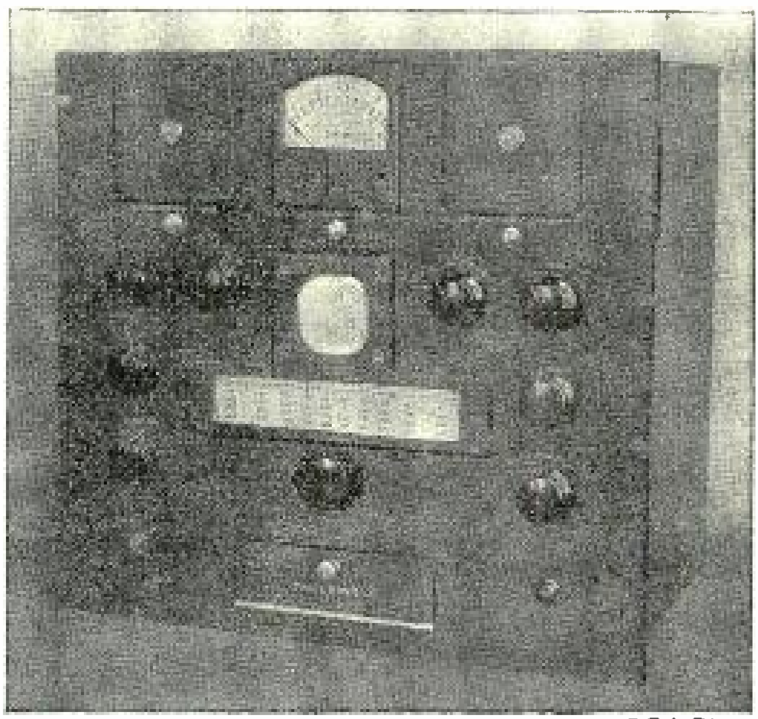
where I_L = transmission line current in amperes

W = power in the radiator (antenna current squared × antenna resistance)

Z_o = characteristic impedance of transmission line.

Before applying the power to the modulation and final stages, the associated overload relays should be checked to assure satisfactory operation. This may be done by applying a low d-c voltage of approximately 10 volts between the center tap and ground of the filament transformer secondaries of the circuit tested. This will cause sufficient overload current to flow to operate the relays.

The final stage may then be tested by applying low power to the stage with the modulator power opened so that no power is being ap-



RCA Photo

Fig. 20-9. Panel view of a direct-reading phase monitor for use in directional antenna arrays, providing a continuous indication of antenna current phasing.

plied to the modulators. The tank circuit is then adjusted to resonance by the usual procedure. If everything is still normal, the high power may then be applied. Checking of correct neutralization to assure that no spurious oscillation exists may be made by removing one of the crystals from the spare crystal circuit so that the oscillator selector switch may be thrown to this circuit to kill the oscillator circuit with low power applied to the final stage. This should cause all grid currents to drop to zero.

The final stage plate supply should then be opened at a convenient point and power applied to the modulator plates and the static plate currents adjusted by the means provided. If trouble is experienced in bringing the static plate current down, it may be that the inverse feedback circuit is improperly phased. This is, of course, easily determined by reversing the connections of the feedback circuit and observing the effect on the modulator plate current.

Fig. 20-9 shows a direct reading phase monitor (Type WM-30A, RCA) for use in directional antenna arrays, which provides a convenient visual indication of antenna current phasing to the operator at all times. The proper phase relations must be held within the tolerable limits continually. (The schematic diagram of this instrument and technical information pertaining to its use will be found in the Appendix.)

Factors Affecting Hum and Noise

Noise and distortion measurements as outlined in Part 4 of this Handbook are a very important part of the transmitter personnel's duties. Hum and noise in transmitters is most commonly traced to the following factors:

(a) Grid excitation to the modulated amplifier
(b) Filament balancing resistors
(c) Phase balancing resistors for tubes using split filament construction of 90° phase relation to reduce effect of a-c filament supplies.

When a noise measuring meter is used, these resistors should be adjusted to achieve minimum balance of the 60- and 120-cycle components.

In order to achieve the lowest noise and distortion factor in a transmitter, the following points should be observed:

Correct filament and plate voltages
Sufficient grid excitation to modulated stage
Accurate neutralization
Correct grid-leak bypass capacitance on modulated stage

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APPENDIX*

RCA 96-A LIMITER AMPLIFIER

The dynamic balance of the push-pull input tubes is an important adjustment for the limiter type amplifier, since tubes that are not dynamically balanced will cause an audible "thump" on sudden program peaks. The following applies to the RCA Type 96-A limiting amplifier.

Check the dynamic balance of the 6K7 input tubes as follows: after installing 6K7's, let them heat for about 10 minutes. Turn the meter switch on the panel to the "VI" position, the "6K7 MATCH" switch on the chassis to "CHECK," and the "OUTPUT CONTROL" attenuator to plus 18 (wide open). If the meter reads above the "6K7 MATCH" range on the scale, another combination of tubes must be tried until the proper match is obtained. If the reading is within the range, turn the "6K7 MATCH" switch to "OPERATE." This switch must, of course, never be turned to "CHECK" during the program, and the *modulator should be turned off or disconnected during this check.* The output of the 96-A amplifier, however, must be properly terminated.

The HUM adjustment is also on the chassis of the 96-A, and should be checked periodically, especially after installing new input tubes. An auxiliary amplifier of at least 60-db gain should be used for this check. The output of the 96-A should be fed through this auxiliary amplifier, and checked with headphones on the output of the extra amplifier. It will be noticed that the HUM adjusting screw may be swung through a fairly wide arc where minimum hum occurs, and should be adjusted in the center of this arc.

RCA DISTORTION AND NOISE METER

Description

The Type 69-C Distortion and Noise Meter was developed to supply an accurate and reliable instrument for measuring the harmonic distortion and noise level in the output of radio transmitters, audio ampli-

* Illustrations and other material furnished through the courtesy of RCA Mfg. Co.

fiers, or modulated radio-frequency equipment of any type. Distortion or noise measurements are read directly from the meter scale, which is calibrated for several ranges. When used with the Type 68-A or 68-B Low Distortion Oscillator, distortion measurements may be made at any frequency from 50 to 8,500 cycles per second or higher with weighting of the harmonics as indicated in the TECHNICAL SUMMARY under Frequency Range. Reliable readings as low as 0.3 percent may be made on any equipment having less than 180 degrees phase shift throughout its frequency range. Under these conditions, the inherent distortion in the oscillator approximates 0.1 percent rms, which will have a negligible effect upon the distortion meter readings. Under the worst possible phase conditions, a residual reading of approximately 0.2 percent would be obtained.

Distortion measurements may be made at frequencies down to 20 cycles per second with reasonable accuracy if the amount of distortion to be measured is not too small. Using 1 mw in a 600-ohm line as a zero reference level, distortion can be measured at volume levels as low as —17 db and noise levels may be measured as low as —75 db.

The essential elements of the 69-C Distortion and Noise Meter are as follows:

(1) An input circuit for the essentially sinusoidal signal from the 68-A or 68-B Beat Frequency Oscillator, including a level control, marked "CALIBRATE," and a phase-shift network comprising three controls—coarse, medium, and fine, as shown in Fig. A-1.

(2) An input circuit for the distorted signal from the equipment

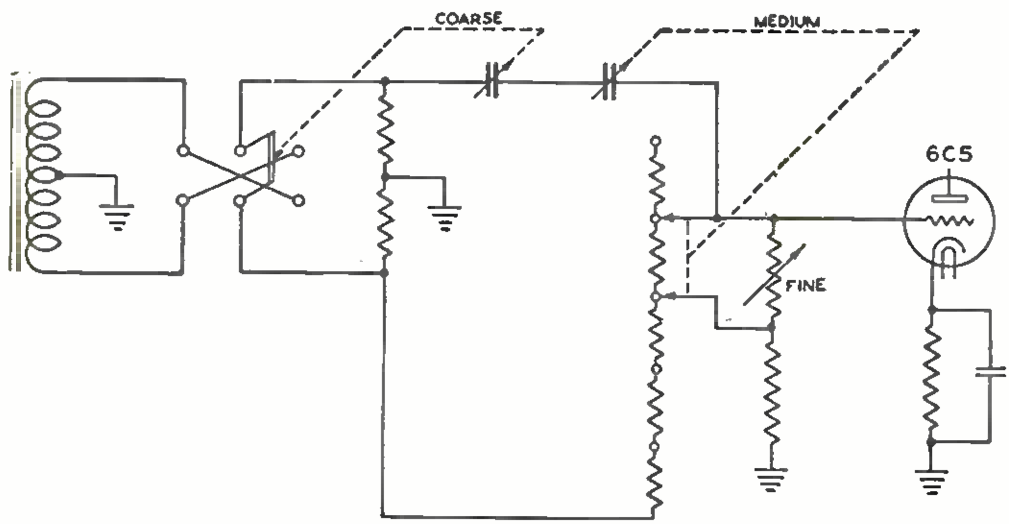

Fig. A-1. Partial schematic of the distortion and noise meter showing the level control and the phase-shift network.

under test. This includes a rectifier for demodulating an r-f signal when desired, a selector switch marked "INPUT," a source of voltage for standardizing the gain of a voltage amplifier, and three level controls—coarse, medium, and fine, as shown in Fig. A-2.

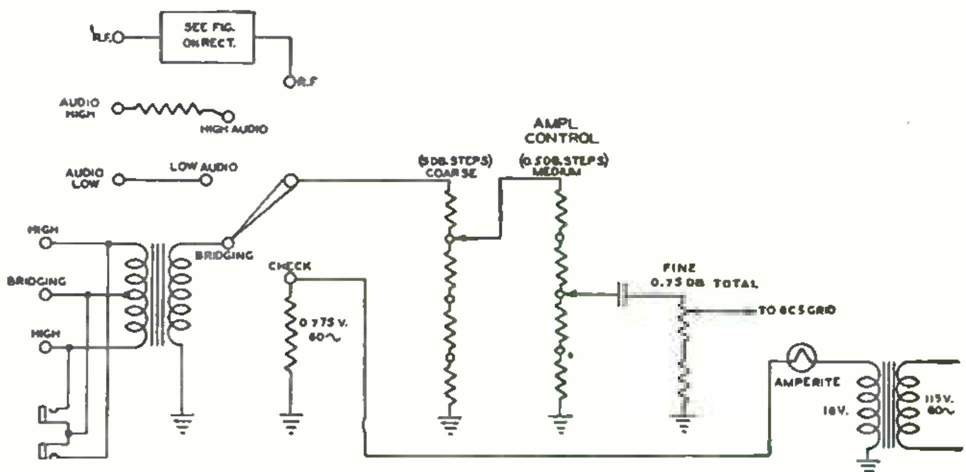

Fig. A-2. Input circuit for the distorted signal from the equipment under test, including a rectifier, selector switch, and level controls.

(3) A push-pull amplifier stage which is used as a normal amplifier for noise level measurements, and as a cancellation stage for distortion measurements.

(4) A "DISTORTION-NOISE LEVEL" switch, which is used for circuit switching and for controlling the attenuation between the push-pull amplifier stage ((3) above) and the voltage amplifier.

(5) A three-tube voltage amplifier with negative feedback. The "GAIN" control determines the gain of this amplifier by controlling the amount of feedback.

(6) A detector and output meter, for measuring the rms value of signal. A small amount of bucking current is fed through this meter to buck out the no-signal plate current of the detector. The amount of bucking current is controlled by the "ZERO" control. Fig. A-3 illustrates the distortion measurement circuit.

(7) A power supply furnishing heater, plate, and screen voltages, and the standardizing voltage mentioned in (2) above.

In making distortion measurements, the meter indicates the distortion factor—i.e., the ratio of rms total distortion to the fundamental amplitude. This is accomplished by suppressing the fundamental frequency component of the wave in question and measuring the rms total of the remaining components. Elimination of the fundamental frequency component is accomplished by adding to the distorted wave a sine wave of the same frequency, equal in amplitude to the fundamental component, but 180 degrees displaced in phase. This voltage is secured from the same oscillator which supplies the signal to the equipment under test and is adjusted in amplitude and phase by the use of

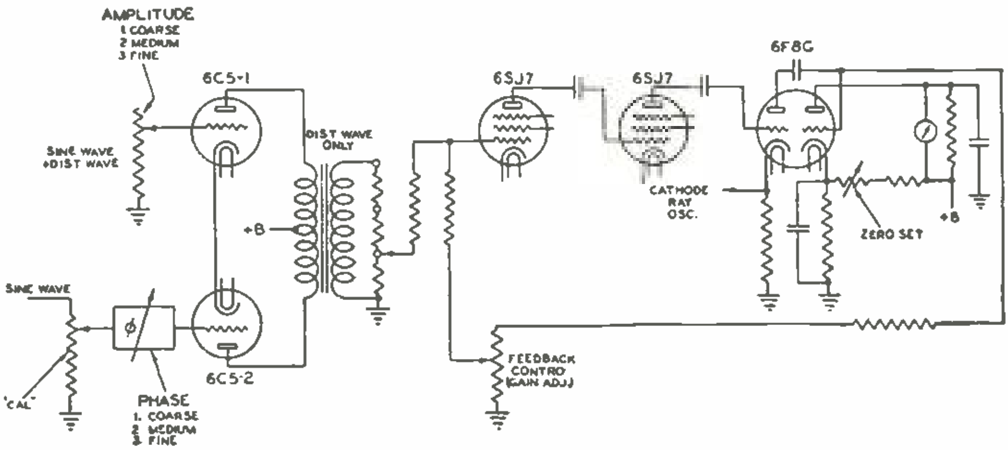

Fig. A-3. Distortion measurement circuit consisting of a detector and output meter through which a small current is fed to buck-out the no-signal plate current of the detector.

the controls on the panel of the Distortion and Noise Meter. Distortion readings directly in per cent of the fundamental amplitude are obtained by first adjusting the meter to read full scale (100%) with only the sine wave input connected.

Measurements of noise levels are made by adjusting the meter for full-scale deflection at the desired equipment output level and then removing the input signal from the equipment under test. The remaining noise and hum is amplified until a reliable meter deflection is obtained. The noise level is then read directly in decibels from the meter and attenuator scales.

Installation

The power cable should be connected between the a-c receptacle of the meter and a power supply outlet furnishing 105-125 volts, 25-60 cycles and delivering 50 watts. The power line fuse on the chassis should be in the proper position corresponding to the applied line voltage. Terminals for connecting the Distortion and Noise Meter with the associated equipment are located on the rear of the chassis with parallel-connected jacks located on the front panel.

The pickup circuit used for modulated r-f signals must provide a low-resistance d-c path between the r-f and ground terminals of the distortion meter as well as low audio-frequency impedance.

These conditions will be met by the use of a small pickup coil consisting of several turns. Capacitative coupling or an antenna may be used if a radio-frequency choke or a parallel resonant circuit is connected across the r-f and ground terminals. A low resistance, untuned coil is the most desirable for this purpose, as it is least likely to introduce hum into the circuit or to cause frequency discrimination.

The chassis of the Distortion and Noise Meter should be well grounded to minimize stray r-f pickup. This can be accomplished by the use of a heavy strap or braid, as short as possible.

Operation

Distortion and noise measurements are read from the same meter, which is calibrated to the following full scale readings:

Distortion	Noise Level
1%	−50
3%	−40
10%	−30
30%	−20
100%	−10
	0

The desired meter range is selected through the meter range switch, which is controlled by means of the large knob and scale. The desired distortion range may be selected by rotating the knobs over the left half of the scale. The desired noise level range may be selected by rotating the knob over the right half of the scale.

INPUT LEVELS—For accurate distortion or noise measurements, the input levels to the instrument should be adjusted to within the following limits:

Modulated r-f—10 volts to 80 volts.

To determine the proper r-f input level modulate the transmitter approximately 100 percent and set the "DISTORTION-NOISE LEVEL" switch at "0." Adjust the input level until full-scale meter reading is obtained with the "AMPLITUDE" control set between "0" and "+16."

Audio frequency from 68-A or 68-B oscillator—2 volts to 4 volts.
Audio frequency from equipment under test—

1. Bridging input terminals or jacks (balanced)
   Minimum—0.14 volts or −15 db below 1 mw on 600-ohm line.
   Maximum—9.0 volts or ±22 db above 1 mw on 600-ohm line.
2. Audio and ground input terminals
   (a) "Audio Low"—0.12 volts to 8.0 volts.
   (b) "Audio High"—1.2 volts to 80 volts.

COUPLING METHODS—Modulated radio-frequency voltages to be measured are obtained through inductive coupling. The pickup coil should be designed with a low audio-frequency impedance in order to eliminate any a-c hum component that may be picked up.

When the Distortion and Noise Meter is to be used in conjunction with a balanced audio line having an impedance of 600 ohms or less, a bridging transformer having an impedance of 20,000 ohms is provided. This impedance is sufficiently high to have no appreciable effect upon the low-impedance line. The three transformer input connections terminate in three binding posts, marked "BRIDGING," located at the rear of the chassis, and a pair of parallel connected jacks located on the front panel. The center tap of the transformer winding is not grounded.

CONNECTIONS—Following are tabulated the correct connections to be made for distortion and noise measurements under various conditions:

For Modulated Radio-Frequency Input—Connect the pickup coil between the "R-F" and "Ground" terminals at the rear of the instrument and remove all connections from the audio terminal. Set the "INPUT" switch to "R-F" position.

For Audio-Frequency Input Balanced Lines, Up to 600 Ohms—Connect the audio line either to the "BRIDGING" terminals at the rear or to the "BRIDGING" jacks on the front panel. The center tap connection may be connected, left open, or grounded as desired. Set the "INPUT" switch to "BRIDGING" position.

For Unbalanced Audio-Frequency Input—

(a) Below 4 volts
   Connect the audio line to "LOW AUDIO" and ground binding posts.
   Set the "INPUT" switch to "LOW AUDIO."

(b) Above 4 volts
Connect the audio line to "HI. AUDIO" and ground binding posts.
Set the "INPUT" switch to "HI. AUDIO."

For Distortion Measurements—Connect the 250- or 500-ohm 68-A or B oscillator terminals to the two terminals at the rear of the distortion meter marked "OSCILLATOR," or to the pair of jacks on the front panel marked "OSCILLATOR."

For Oscillograph Indication—When desired, a cathode-ray oscilloscope may be connected to the "CRO" binding posts to observe wave form of distortion or noise, or to assist in balancing out the fundamental. Any circuit connected across these binding posts should have an impedance of at least 100,000 ohms, and when an r-f field exists, such as around a transmitter, a shielded lead should be used.

CALIBRATION—Prior to making measurements, the instrument should be calibrated in the following manner:

1. Turn the power on by rotating the "CALIBRATE" control in a clockwise direction, and wait at least five minutes to allow voltages to stabilize.
2. With no input signal to the "OSC." binding posts or jacks and with the "DISTORTION-NOISE LEVEL" switch at the "CALIBRATE" position, adjust the "ZERO" control for a meter reading of zero per cent (not 0 db).
3. Set the coarse and medium "AMPLITUDE" controls to "0" positions and the "FINE" control with the pointer approximately vertical. Also set the "DISTORTION-NOISE LEVEL" switch to the "0" position, and the "INPUT" switch to the "CHECK" position. Adjust the "GAIN" control for full-scale meter reading (0 db).

NOISE LEVEL MEASUREMENTS—

Noise levels may be measured in either of two ways. One method gives a result in terms of the standard zero level of the 69-C, which is 1 milliwatt in a 600-ohm line. The other method gives a result in decibels below some arbitrary output level of the equipment under test. The first method is accomplished as follows:

(a) When using "LOW AUDIO" input, it is only necessary to remove input from equipment under test and adjust the "AMPLI-

TUDE" controls and the "DISTORTION-NOISE LEVEL" switch until the meter reads on scale. The noise level (based on a 600-ohm line) is then read from the control settings and the meter readings.

(b) When using "HI. AUDIO" input, a close approximation can be obtained by using the above procedure and adding —20 db to the result.

(c) When using "BRIDGING" input, a close approximation can be obtained by using the above procedure and adding —1.5 db to the result.

The second method, which is the most accurate, is accomplished as follows:

1. Adjust the input to the device under test to obtain the output level below which it is desired to measure the noise level.
2. Adjust the "AMPLITUDE" and "DISTORTION-NOISE LEVEL" controls to obtain a meter reading of "0" db.
3. Remove the input signal from the device under test and move the "AMPLITUDE" and "DISTORTION-NOISE LEVEL" controls until the meter reads on the db scale. The sum of the amount that it was necessary to move the controls and the established meter reading denotes the noise level with respect to the original level.

DISTORTION MEASUREMENTS:

Audio measurements—

1. Apply input signal from the low-distortion oscillator to the "OSCILLATOR" input of the Distortion and Noise Meter, place the "DISTORTION-NOISE LEVEL" switch on "CAL." and adjust the "CALIBRATE" control for a full-scale meter reading. This setting should remain unchanged.
2. Adjust the input to the equipment under test to the desired level, remembering that output must be within the limits specified in input levels above.
3. Place the "DISTORTION-NOISE LEVEL" switch on "0," the "INPUT" switch on appropriate position, and adjust the "AMPLITUDE" controls for full-scale deflection of the meter.

4. Place the "DISTORTION-NOISE LEVEL" switch on "100" and adjust the "PHASE" controls until meter reading is below the calibrated portion of its scale. Turn the "DISTORTION-NOISE LEVEL" switch to "30" and by further adjustment of the "PHASE" and "AMPLITUDE" controls, obtain a minimum meter reading, turning the "DISTORTION-NOISE LEVEL" switch for increased sensitivity as required.

With the selector switch placed on "CAL," during distortion measurements, the meter reading may vary with the position of the "PHASE" controls. This is a normal characteristic resulting in an error of not more than 10 per cent on the "% DISTORTION" scale indication. In order to eliminate this error, place the selector switch on "CAL," after adjusting the phase controls for a balanced condition and readjust the "CALIBRATE" control for a full scale meter indication. A slight readjustment of the "FINE" amplitude control will then be necessary for the final balance.

After obtaining an exact balance, the amount of total distortion is obtained by reading both the "meter" and "switch" scales. After a reading has been taken, the switch should be returned to the "CAL." position before making any adjustments to the equipment, in order to protect the meter.

CIRCUIT LOADING—The output of the Type 68-A Beat Frequency Oscillator should terminate in the correct impedance in order to secure minimum distortion of the oscillator signal. The correct terminating impedance is indicated at each pair of output terminals. To illustrate, an impedance of 500 ohms should be connected between the two terminals marked 500, or an impedance of 250 ohms between each terminal marked 500 and the center tap terminal. The Type 89-A Attenuator Panel will provide proper impedance loading.

EFFECT OF NOISE ON DISTORTION MEASUREMENTS—The Type 69-C Distortion and Noise Meter indicates the rms total of all components of the input signal which fall within the limits of the frequency range. The exception is the fundamental frequency component, which is canceled by the voltage taken directly from the oscillator. The reading of the meter will therefore include the following components:

Component	Frequencies for 1,000 cycle modulation (60-cycle power supply)
(1) Harmonics..................	2,000, 3,000, 4,000 . . 20,000, etc.
(2) Modulation cross products between hum and fundamental....	1,000 + 60 = 1,060
	1,000 − 60 = 940
	1,000 + 120 = 1,120
	1,000 − 120 = 880
	1,000 ± 180 = etc.
(3) Modulation cross products between hum and harmonics......	2,000 ± 60 = 2,060 and 1,940
	2,000 ± 120 = 2,120 and 1,880
	2,000 ± etc.
	3,000 ± 60 = 3,060 and 2,940
	3,000 ± 120 =
	3,000 ± etc.
	4,000 ± etc.
(4) Hum components.............	60, 120, 180, etc.
(5) Noise components............	All frequencies

The Distortion and Noise Meter sums all these quantities and thus indicates, as per cent distortion, the ratio of the sum of all undesired components to the fundamental frequency component. If it is desired to determine the distortion due to the harmonic and cross-product components alone, either of two methods may be used.

One method is to operate the equipment under test at a high output level, which results in making the hum and noise components negligible compared to the other components. Another method is as follows:

1. Measure distortion in the normal manner at the desired output level.
2. Measure the noise level in decibels, using the same output level as a reference level.
3. Convert the reading in decibels to percent; for example, −40 db = 1%, −60 db = 0.1%.
4. These values may then be substituted in the following equation:

$$H = \sqrt{D^2 - N^2}$$

where H = total harmonic and cross section distortion in percent

D = distortion percent obtained as per (1).

N = noise (in percent) obtained as per (2) and (3).

When making distortion measurements, it should be kept in mind that the noise level in the output of the beat frequency oscillator approximates 50 db below 1 milliwatt and is substantially independent of the actual oscillator output voltage. While the design of the distortion meter is such that the effects of noise and distortion present in the oscillator output tend to be canceled out, in most cases the cancellation will be more complete for the distortion than for the noise components.

Therefore, it is desirable to operate the oscillator at as high an output as practicable, thus improving the signal to noise ratio to the point where the noise output of the oscillator (expressed in percent of signal) is small compared to the percent distortion being measured. High oscillator output may not always be consistent with the input voltage requirements of the meter, but this difficulty can readily be overcome by the use of one or two attenuator pads or the 89-B attenuator panel.

When operating the Noise and Distortion Meter at a point remote from the oscillator, the effects of noise and distortion in the line may be great enough to affect seriously the accuracy of the measurements. Hence this type of operation is not recommended.

Normally, when taking measurements near 0 or 180 degrees phase shift, a balance cannot be obtained at frequencies which are transmitted through the equipment under test with phase shifts which fall within these narrow limits. This, however, can be overcome by inserting a capacitor in series with one of the two outside terminal connections (not the center tap) between the distortion meter and oscillator. The value of the capacitor and the choice of which connection to use is best decided by trial.

Maintenance

Service generally consists of replacing tubes which have become defective through usage. All tubes should be tested at regular intervals in a tube tester.

The Distortion and Noise Meter is protected by a 1.5-ampere fuse. Should the clips holding this fuse become unduly heated through improper contact, the fuse will blow. Hence the holding contacts should be free from foreign matter and hold the fuse firmly in place.

Resistance elements through constant usage, sometimes become altered in value. This change, if sufficiently great, will affect operation in that portion of the circuit in which the resistance element is located.

Check tube socket voltages against the values in the table below. In

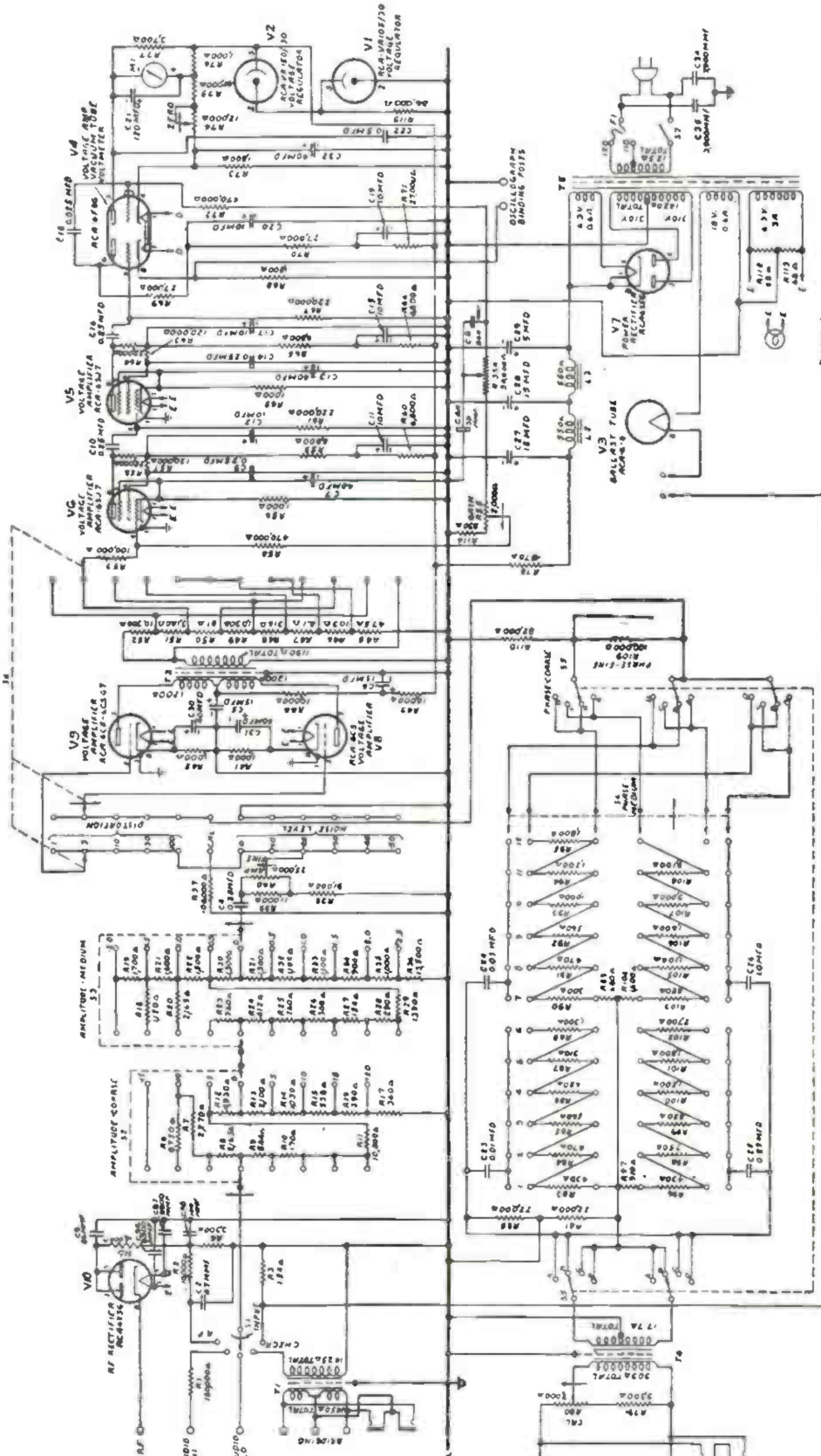

Fig. A-3(A). Schematic diagram of the distortion and noise meter.

event that the check on the tubes does not remove the cause of fault, disconnect the Distortion and Noise Meter from its source of power. With an ohmmeter, check through the entire equipment for continuity.

If such procedure shows the circuit to be intact, then check each element therein with the ohmmeter and compare the resistance readings of the resistors against the corresponding resistor given in the schematic, Fig. A-3(A).

In testing capacitors for open, short, and leaky circuits, it is necessary to remove one side of the capacitor under test from the circuit in which it is connected. The probes of the ohmmeter are then placed across the terminals of the capacitor under inspection and from the nature of the ohmmeter deflection, the condition of the capacitor can readily be ascertained. In the event that R55A, C8, C8A or T2 require replacement, it will be necessary to readjust R55A so that the Low Audio response is flat within ±0.5 db from 30 cycles to 40,000 cycles, and down not more than 1 db at 45,000 cycles. Potentiometer R55A is located underneath the chassis, on the shield.

Tube Socket Voltages

(120-volt line, fuse in 120-volt position)

All voltages except filament are d-c to ground, measured with a 20,000-ohm-per-volt voltmeter.

Tube	E_f a-c	E_p	E_{sg}	E_k	E_p#2	E_k#2
6X5G R-F Diode	6.3					
6C5............	6.3	120	—	3.7	—	—
6C5............	6.3	120	—	3.5	—	—
6SJ7...........	6.3	152	112	3.8	—	—
6SJ7...........	6.3	152	112	3.8	—	—
6F8-G..........	6.0	105	—	3.6	250	11.5
6X5-G..........	6.3	d-c out = 357, a-c pl. to pl. 600 volts rms				
VR105/30......		105				
VR150/30......		255				
Amperite 6-8....	12.0					

RCA PHASE MONITOR

1. APPLICATIONS

Relative Indications of Antenna-Current Amplitude and Phase

The WM-30A Phase Monitor is designed primarily for remote indication of the relative amplitude and phase of antenna currents in arrays employing up to three elements. It is indispensable in maintaining the correct relationships between phase and magnitude of currents in the directive array.

Measuring Phase Shift in Television I-F Circuits

Another important application of the instrument is its use in measuring the phase characteristics of television i-f circuits. This requires the use of an i-f signal generator, two mixer stages and a variable-frequency oscillator interconnected as shown in Fig. A-4. Output

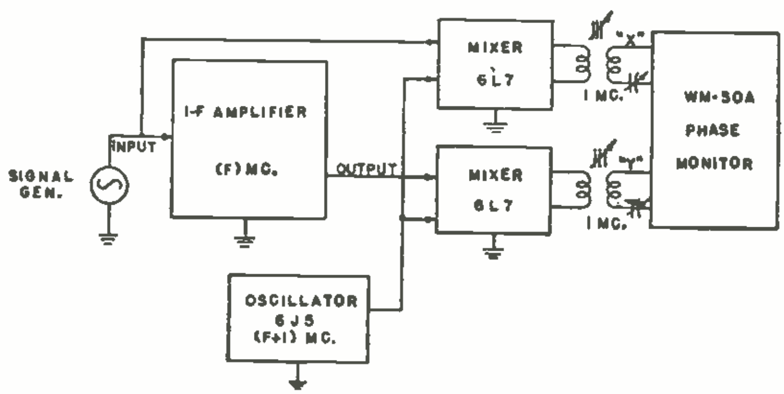

Fig. A-4. Block diagram of equipment for measuring phase shift in television i-f circuits.

from the common oscillator is fed to both mixers to beat with the input and output voltages of the circuit under test. In operation, the beating oscillator is tuned 1 megacycle higher than the signal generator, and thus provides 1-megacycle output voltage from each mixer. The phase difference between the two mixer output voltages can be measured by the Phase Monitor, and corresponds to the phase difference existing between the input and output voltages of the i-f circuit. Fig. A-4 shows the use of 1-megacycle i-f transformers for coupling energy to the Phase Monitor. These transformers should have medium Q and must be carefully tuned to the 1-megacycle frequency to permit accurate phase measurements. The 1-megacycle beat frequency has been chosen arbitrarily as convenient for feeding into the Phase Monitor. Other beat frequencies can be used but it is advisable not to use a lower beat frequency when the signal generator and r-f oscillator are operating at high frequencies. Also, for operation above 20 megacycles, it might be advisable to use mixer tubes which are better adapted to the higher frequencies.

2. DESCRIPTION

The RCA WM-30A Phase Monitor consists of a current indicating

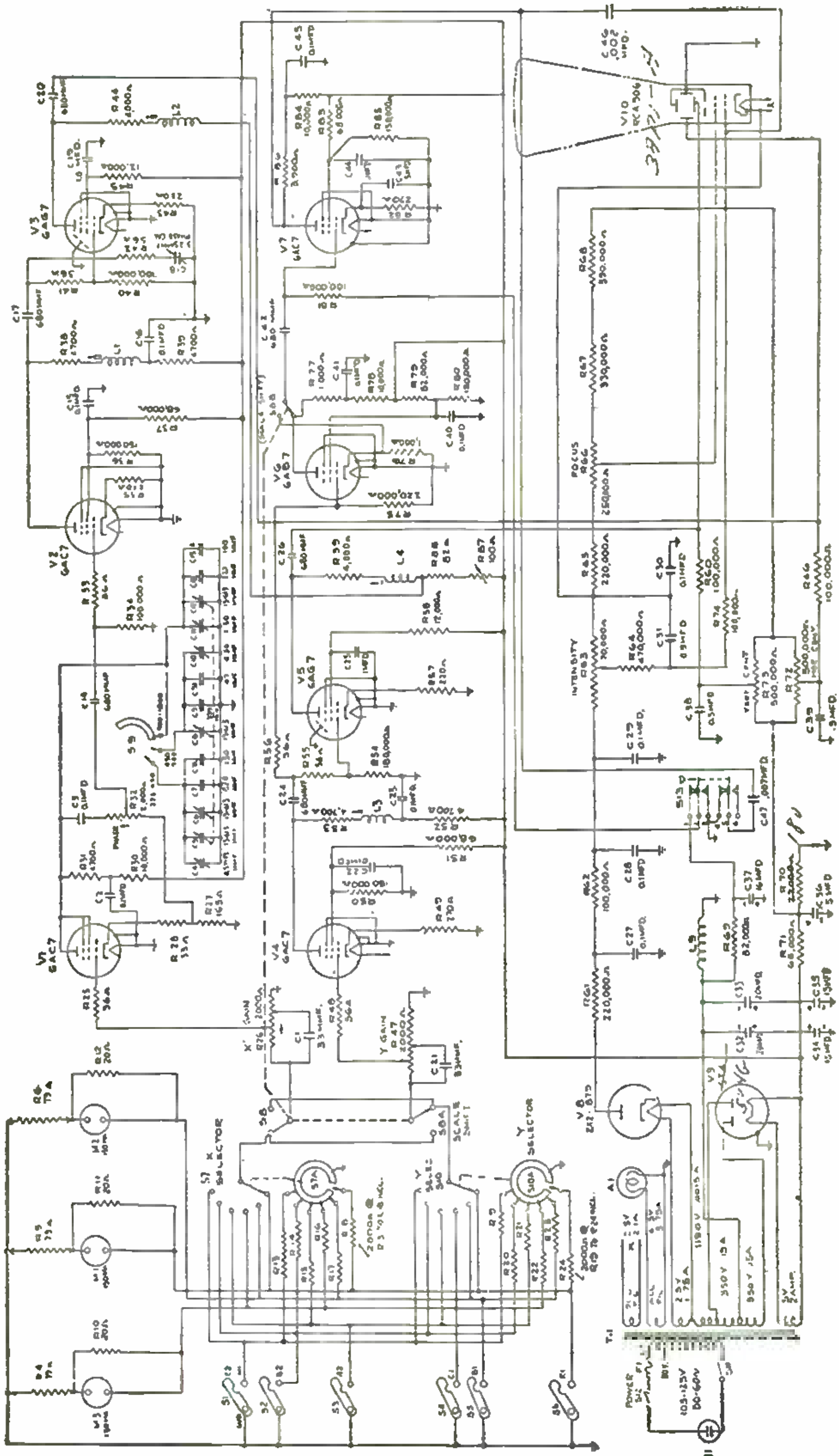

Fig. A-5. Schematic diagram of the phase monitor.

panel which can mount three thermogalvanometers, and associated fixed series and shunt resistances to provide proper termination for three input lines. It also includes vertical and horizontal amplifiers, a calibrated phase shifter, a blanking system and the 3-inch cathode-ray tube. A built-in power supply furnishes high and low voltages for operation of all stages.

A_1, B_1, and C_1, shown in the schematic, Fig. A-5, provide for connection of three r-f input transmission lines. Internal connections are such that an antenna meter shunted by a 20-ohm fixed resistance is connected in series with each sampling line; the resistance of the shunted meter is about 4 ohms. A 79-ohm plug-in resistor is provided to terminate each 79-ohm transmission line, but different values of plug-in resistors can be obtained to make the termination correct for different line impedances. While numerically the sum of the plug-in resistor and the series resistance of the meter (4 ohms) does not equal the termination resistance, a correction has been made in the value of the series resistor to compensate for the shunting effect of the phase measuring input circuit, which is connected directly across the sampling line. From the sampling lines, the inputs to the phase measuring circuits are connected to the two "SELECTOR" switches. When the "SELECTORS" are switched from one sampling line to another, a load substitution is made, thereby maintaining constant loading on the lines.

The Phase Measuring Circuit

A block diagram of the phase measuring circuit is given in Fig. A-6. As shown by the diagram, the "X" input and "Y" input voltages as

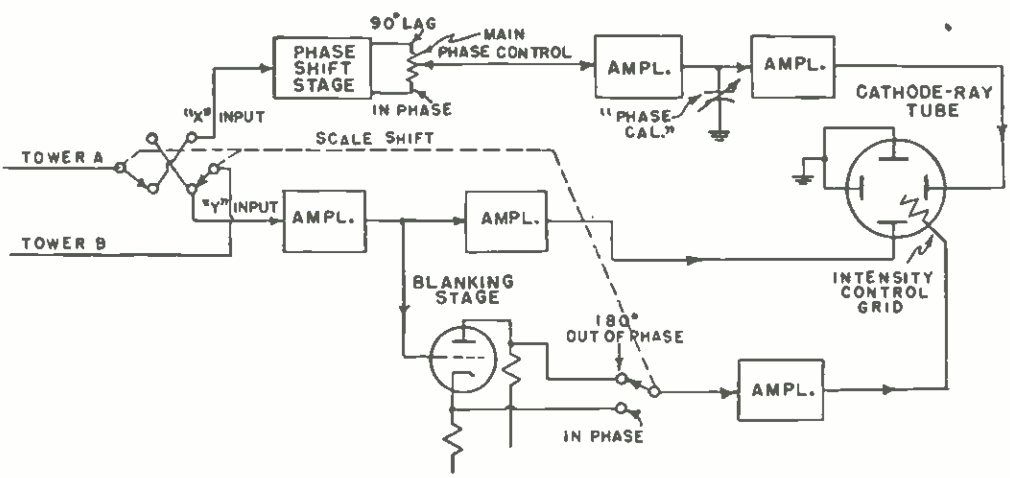

Fig. A-6. Block diagram of the phase monitoring circuit.

provided by sampling lines from towers A and B, are fed through the "SCALE SHIFT" switch to the horizontal amplifier channel "X" and the vertical amplifier channel "Y." It should be noted that one function of the "SCALE SHIFT" switch is to reverse the "X" and "Y" channel inputs. Input to the "X" channel is fed through a phase shifter stage which will provide in the "X" channel a 0–90-degree (maximum) phase lag behind "Y" channel depending on the setting of the main phase control ("X-LEADS-Y") on the front panel. The blanking stages in the "Y" channel operate to blank part of the trace at the proper instant, thus indicating the proper quadrant and, hence, the correct scale to be read. Operation of the phase shifting and blanking stages is described later.

In preliminary adjustment, both "SELECTOR" switches are placed in position to select voltage from the same sampling line, thus assuring in-phase input to both the "X" and "Y" channels. The "X-LEADS-Y" main phase control is set on "0," to produce no phase shift. The "PHASE CAL." control, a small compensating trimmer (C18) connected between V2 and V3 in the "X" amplifier, is adjusted if necessary, to make the over-all phase shift in the "X" amplifier identical to that in the "Y" amplifier. C18 is controlled by a knob behind the small door in the front panel. Then, since in-phase voltage is applied to the input of both amplifiers, the voltages applied to the horizontal- and vertical-deflection plates of the cathode-ray tube will be in phase, producing an oblique, straight-line trace on the screen. Conventional controls are provided for horizontal and vertical amplitude control and for centering of the trace. If there is a phase difference between the sampling lines to be measured, changing the "SELECTOR" switches to these lines will then cause out-of-phase voltages to be applied to the deflection plates of the cathode-ray tube; the phase relationship of these voltages being identical to that existing between the "X" and "Y" inputs under observation. At this point, a phase correction is made in the "X" channel by means of the main phase control ("X-LEADS-Y") to produce again in-phase voltages at the deflection plates, and the amount of phase correction required is indicated directly in degrees as the phase differences existing between the input lines.

Inasmuch as the phase shifter stage provides for a maximum phase shift of 90 degrees, and since it is desirable to have indications as given by the scale on the front panel always in terms of "X" leading "Y," provision was made for reversing the "X" and "Y" inputs for cases where the phase difference between the sampling lines is greater than 90 degrees or when the phase of the voltage in the "Y" sampling line leads that in the "X" line. This is one function of the "SCALE SHIFT" switch.

Another function of the "SCALE SHIFT" switch is to shift the phase of the blanking signal 180 degrees, providing positive determination of the quadrant in which the measured phase angle lies. Operation of the blanking stages take place when the front panel scale check button is pressed. A detailed description of the blanking system follows.

The Blanking Stages

As can be seen in the block diagram, Fig. A-6, when the "SCALE SHIFT" switch is in one of its two positions, tower A feeds the "X" channel and tower B feeds the "Y" channel. Assuming that tower A is leading tower B by 180 degrees, that no phase shift is introduced in the phase shifting stage, and that identical phase shift is present in each amplifier, then voltages 180 degrees out-of-phase will be applied to the horizontal and vertical deflection plates, and an oblique straight line will appear on the screen as shown in Fig. A-7(A). The slope of the line will vary with adjustment of the gain controls, but the direction of the slope will not shift. When the scale check button is pressed, the blanking signal applied to the control grid of the cathode-ray tube is in phase opposition to the output of channel "Y." Thus the luminous trace will be blanked during its excursion toward the top vertical-deflection plate, and slightly intensified during the opposite half of the voltage cycle, when the trace is in the lower right quadrant. The visible portion of the trace, therefore, will be in the lower right quadrant of the cathode-ray tube, as shown in Fig. A-7(B), indicating use of the 90 to 180 degree scale. The phase difference as indicated by the scale pointer is then "180" degrees. However, if the "SCALE SHIFT" switch is now placed in the other position, the voltage from tower A

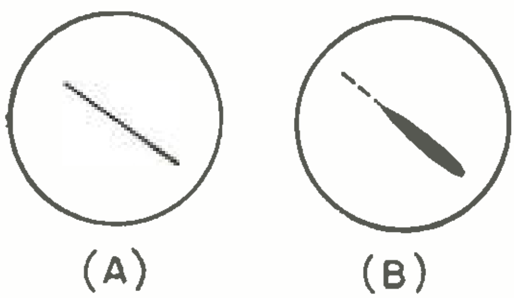

Fig. A-7. Voltage 180 degrees out of phase are indicated on the scope screen by a pattern as shown at (A). When the scale-check button is pressed, part of the trace is blanked out and part intensified as in (B).

(which is leading that of tower B) will be applied to the "Y" channel. But the blanking signal at the cathode-ray tube, will still be in phase opposition to the tower B signal from channel "X" because the "SCALE SHIFT" switch, in addition to reversing the "X" and "Y" inputs, now selects output from the cathode circuit of the first blanking stage instead of its plate circuit, thereby eliminating a 180-degree phase shift which took place in this stage when the switch was in the normal position. Since the inputs are reversed, the blanking will now take place when the trace is in the lower right quadrant of the cathode-ray tube. The visible part of the trace is, in this case, in the upper left quadrant of the tube indicating use of the 180 to 270 degree scale on which the pointer again indicates "180" degrees.

The Phase Shifter Stage

In the examples just cited, no phase shift has been introduced in the phase shifter stage, and since the voltages were assumed to be exactly in phase opposition at the "X" and "Y" inputs and also at the deflection plates, a straight line was obtained on the cathode-ray tube screen in each case. It is well known that when the phase of sinusoidal voltages applied to the horizontal- and vertical-deflection plates differs by angles other than 180 degrees, a variety of elliptical patterns will be obtained depending on the phase angle. Assume now that, in the block diagram, tower A is leading tower B by 90 degrees. The "SCALE SHIFT" switch is in position so that tower A feeds the "X" channel and tower B the "Y" channel; no phase lag is being introduced by the phase shifter stage (main phase control at "0") and initial correction has been made for phase difference in the amplifiers by adjustment of the "PHASE CAL." control. The voltage applied to the horizontal deflection plates, therefore, will lead by 90 degrees the voltages applied to the vertical deflection plates, and the pattern observed on the screen will be nearly circular. In order to measure the phase difference in this case, it is necessary to adjust the main phase control, which will introduce a phase lag in the "X" amplifier, until the circular pattern becomes a straight line. The amount of phase lag introduced represents the phase difference between the two sampling lines and is indicated directly in degrees on the scale. The proper scale to be read ("0-90" degrees in this case) is indicated by the quadrant (lower right) in which the pattern appears when the scale check button is pressed. For cases where "X" leads "Y" by an angle greater than 90 degrees, or when "Y" leads "X," measurements must be made with the "SCALE SHIFT" switch in its other position.

In making measurements, no confusion can result as to the correct position for the "SCALE SHIFT" switch for different phase angles of lead and lag between "X" and "Y." Usually a straight-line pattern can be obtained for only one position of the switch. If the straight line occurs when the phase shift introduced by the phase shifter stage is either 0 or 90 degrees, the straight-line pattern can be obtained in either of the two positions of the scale switch. In any event the scale-check feature determines which scale should be read.

3. INSTALLATION

Connections

The input terminals A_1, B_1, C_1 provide for connection of three sampling lines. The three terminals on the other side (A_2, B_2, C_2) provide for interconnection of the Phase Monitor and the Remote Antenna Current Indicator described later. Use of the Remote Antenna Current Indicator together with the Phase Monitor is not necessary unless more than three antenna elements are to be monitored. Technical and mechanical data regarding the construction of various types of sampling lines and coils is given in Section III below.

In order to obtain the best accuracy in measurements, the sampling lines should be of equal length. If the physical layout of the antenna array is such that this is not practical, correction factors must be applied to all phase measurements to compensate for the differences in phase delays in the sampling lines. The correction may be estimated if both the velocity of propagation of the particular type of sampling line and the differences in their physical lengths are known. However, for precise work, measurements should be made on the lines with an r-f bridge and the exact unbalance in electrical degrees determined. Even when the lines are cut to identical physical lengths an impedance check should be made to prove that the lines are electrically identical. There may be sufficient variation between samples of a given type of line to produce phase unbalances. If unbalance exists, the lines must be trimmed to produce electrical identity. It is important that these lines be terminated in their characteristic impedance. This value depends of course on the type line used. A commonly used type of line has a characteristic impedance between 75 and 80 ohms. The Phase Monitor is supplied with a 79-ohm plug-in resistor (R4, 5 and 6) for each of the three inputs, and this resistor provides a termination impedance of 79 ohms. If lines are used having other values of impedance, plug-in resistors which will provide the correct terminating impedance should be substituted for the resistors supplied.

Preliminary Adjustments

Refer to the frequency curve of Fig. A-8 and set the tuning dial located on the left rear corner of the chassis to the number indicated

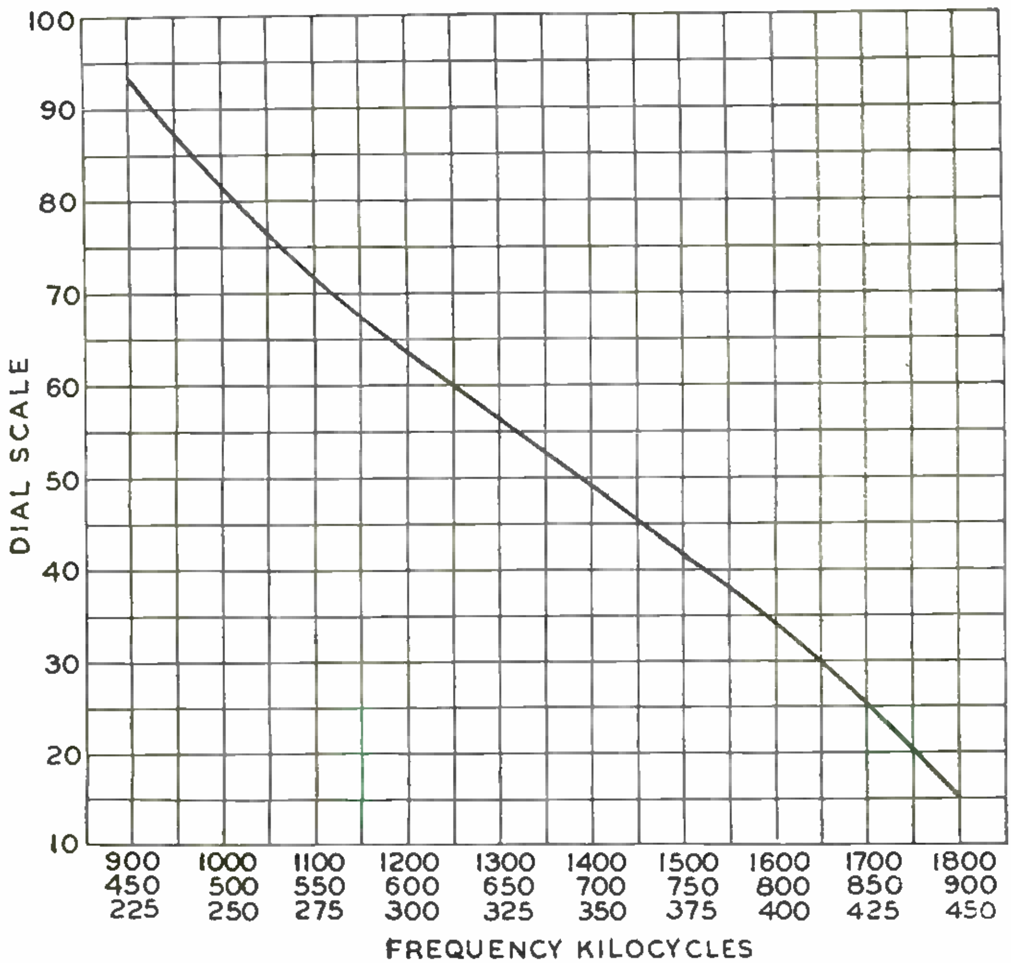

Fig. A-8. Phase monitor frequency vs. dial readings.

on the curve for the frequency used. Then lock the dial. Set the range switch (S9) on top the shield box for the correct frequency range. Replace the dust cover and connect the power cord to a 105-125-volt 50/60-cycle supply.

4. OPERATION

a. Turn on the "POWER" switch, set the "X-GAIN" and "Y-

GAIN" controls at minimum, and the "INTENSITY" control at approximately mid-position. Focus the spot that appears on the screen, by means of the "FOCUS" control, to obtain a sharply defined spot. Adjust the "INTENSITY" control to produce medium brilliance.

CAUTION: If an intense spot is allowed to remain in a fixed position, for even a short time, burning of the screen may result. The horizontal and vertical centering controls, which are located behind the small door on the front panel, will provide for centering the spot.

b. Set the "SELECTOR-X" and the "SELECTOR-Y" each to the *same* line (preferably the line indicating highest current). Turn the main phase control on the front panel until the scale pointer is at the extreme left side of the scale ("0 degree"). Increase the settings of the horizontal and vertical gain controls until a pattern of convenient size is obtained. The settings of these controls must not be changed after the next step is completed. The pattern obtained should be a slanting straight line. If an ellipse appears instead, adjust the Phase Cal. control, located behind the small door on the front panel, until the pattern is a straight line of minimum width.

c. Change the X and Y "SELECTOR" switches to the lines between which the phase shift is to be measured. The straight-line pattern will probably become an ellipse. Rotate the main phase control, and if necessary shift the "SCALE SHIFT" switch to its other position, to obtain a straight line of minimum width. Then press the scale check button which will cause a portion of the trace to disappear. The visible part of the trace will then appear in one of the four quadrants of the screen indicating which of the four scales should be read. The phase difference of the two sampling lines is thus indicated directly in degrees. Since phase differences are always indicated in terms of "X" leading "Y," the setting of the "SELECTOR" indicates the leading line, i.e.; A_1, B_1, or C_1.

Unless the amplitudes of the voltages on the "X" and "Y" channels differ very widely, there can be no doubt in which quadrant the trace is located. In an antenna array, the currents do not usually vary to the extent that the straight-line pattern is so nearly horizontal or vertical that it is difficult to determine the correct quadrant.

If measurements are to be made at more than one frequency, it will be necessary to reset the tuning dial at the rear of the chassis to the setting specified on the calibration chart. The amplifier balancing adjustment should be checked after any change in frequency.

If it is necessary to readjust the amplifier gain controls to maintain adequate pattern size during a measurement, the phase calibrating adjusting should be checked for the new settings of the gain controls.

5. MAINTENANCE

A schematic diagram (Fig. A-5) and a table of tube socket voltages are included as an aid in servicing the equipment. Voltages varying considerably from those shown is an indication of trouble in the circuit.

In general, tubes can be replaced with others of the same type without the necessity for circuit readjustment. In the event that proper phase calibration cannot be obtained by manipulation of the Phase Cal. control, a slight readjustment of the plate inductances (L1, 2, 3 and 4) will enable the calibration adjustment to be made. These coils are provided with screw driver adjustments which are all accessible from the top of the chassis.

WM–30A Phase Monitor
Table of Socket Voltages

Tube or Place	Plate	Screen	Sup.	Cathode	Fil.	Grid
RCA-6AG7 output	250	300	0	9.8	6.3	0
RCA-6AC7 X channel	295	165	0	2.5	6.3	0
RCA-6AC7 Y channel	295	165	0	2.5	6.3	0
RCA-6AC7 phase shift tube	160	160	160	3	6.3	0
RCA-6AC7*	380	260	0	0	6.3	−32
RCA-6AC7**	245	160	0	3.3	6.3	0
RCA-6AB7 blanking amp.	330	210	0	6.3	6.3	0
Reactor drop	−33				6.3	
RCA-2X2A	−1100				6.3	
RCA-3AP1A****	0	1st Anode −710		−960	2.5	−840***

* Push-button normal.
** Push-button depressed.
*** Inaccurate because of series resistance.
**** Measured with 11-megohm meter (RCA VoltOhmyst).

REMOTE ANTENNA-CURRENT INDICATOR

1. DESCRIPTION

The Remote Antenna-Current Indicator is designed to give relative indications of the currents in antenna arrays employing up to three elements. The unit provides a means for insuring the correct current relationship between elements, and hence, proper field patterns. It is furnished with a standard rack-mounting panel.

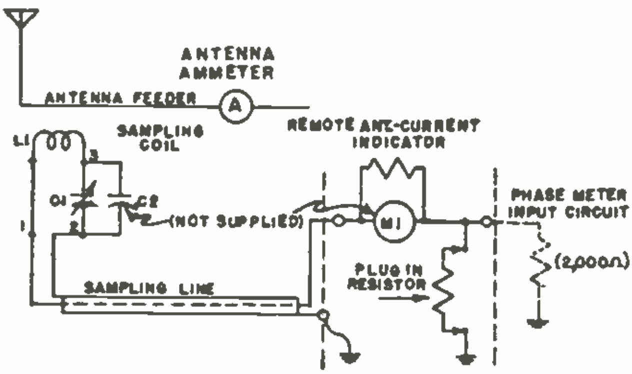

Fig. A-9. Schematic diagram of the remote antenna-current indicator.

Each of the three current measuring circuits are wired as shown in the schematic diagram of Fig. A-9. Resistors R4, 5, and 6 are 79-ohm plug-in resistors to provide the correct termination for sampling lines having surge impedances between approximately 72 and 82 ohms. Plug-in terminating resistors suitable for use with sampling lines having other surge impedances can be obtained on separate order if desired. In general, an exact line match is not necessary, and except for critical line lengths, such as multiples of one-quarter wave, variations of as much as ten percent from the exact value should introduce no appreciable error in either current or phase indications. The plug-in resistors are located on the rear of the unit.

2. INSTALLATION

The equipment is designed for mounting in a standard 19-inch rack. If it is to be used in conjunction with the Phase Monitor, the Remote Antenna-Current Indicator should be mounted either directly above or below the monitor in order that short, direct open bus connections can be made between the two instruments. When this is not feasible, and distances up to 3 or 4 feet are involved, interconnections should be made with concentric line. The capacitance per foot of the interconnecting cables should not exceed 30 μμf. Interconnecting lines of equal length should be used in the sampling line circuits for best accuracy in making phase measurements. Leads should be dressed away from each other to avoid cross-coupling.

The three line terminals at the left rear of the unit provide for connection of three sampling lines. The output terminals at the right provide for connecting the unit to three respective terminals (A_2, B_2, and C_2) of the Phase Monitor. If the Phase Monitor is not used, the output terminals can be left open. Three resistors are included to simulate the load imposed by the input circuit of the WM-30A. When the Phase Monitor is used, these resistors should be removed.

3. SAMPLING ADJUSTMENT

The relative advantages and disadvantages of various methods of sampling, and the construction of suitable sampling lines and coils are described later. Reference should be made to this, particularly if the sampling system to be installed is intended to feed a phase monitor.

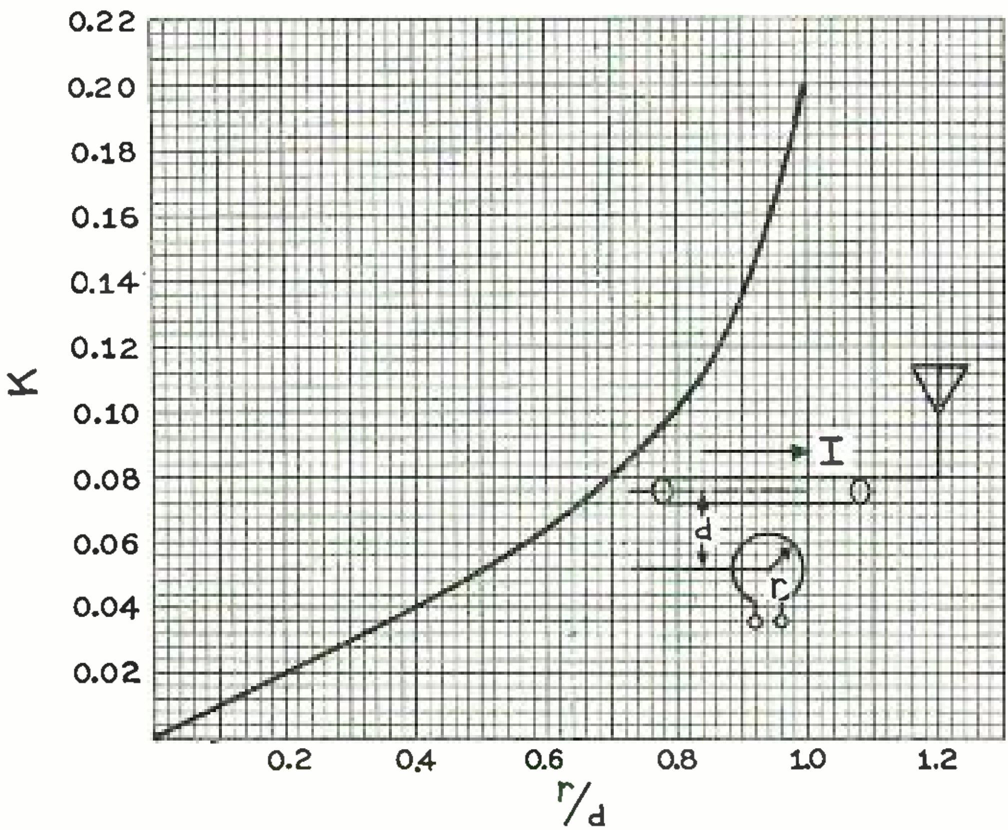

Fig. A-10. Curve for determining the constant K in the formula for calculating the output voltage.

No means is provided in the equipment for adjusting the panel-meter indication. The desired deflection is obtained experimentally by varying the coupling between the sampling coil and the antenna.

Between 5 and 10 volts output is normally required at the output of the sampling coil to provide sufficient excitation for the Phase Monitor and the Remote Antenna-Current Indicator. The coil output voltage can be estimated with reasonable accuracy when the antenna current is known:

$$\textit{Output volts, } E = fNIrK$$

where:

f = frequency in megacycles
N = number of turns
I = antenna current in amperes
r = radius of coil in inches
K = constant derived for distance (d) and radius (r) as given in Fig. A-10.

For example, at a frequency of 1000 kc and with an antenna current of 4 amperes,

if $d = 4$ inches
$r = 1.5$ inches
$N = 54$ turns
then, $E = (1)\ (54)\ (4)\ (1.5)\ (0.04)$
$= 13.0$ volts (approx.)

Slight rotation of the coil from maximum coupling will, in this case, give the desired output voltage.

METHODS OF SAMPLING

This section is a detailed treatment of various methods of sampling, together with their relative advantages and disadvantages as applied to different antenna installations.

1. USE OF TUNED CIRCUITS

a. General

The tuned sampling coil can be coupled at virtually any point along the radiator or feed line in many installations and still pick up enough voltage to operate the current and phase indicators. Considerations involved in locating the coil are discussed in Paragraph 3. The coil can be made small, and if a phase meter is not used, the pickup voltage can be conveniently varied over a limited range by slightly detuning the circuit, rather than by varying the degree of coupling which in some installations presents a mechanical problem. The tuned coil has one disadvantage for use with a phase meter. Unless the coil is kept precisely tuned to transmitter frequency, errors will result in phase measurements due to the reactive component in the sampling unit.

b. Location

Since the tuned circuit is more sensitive than a nonresonant loop, care must be exercised in its location. Otherwise, misleading indications may be produced by pickup from adjacent towers or voltages induced by other inductors in the installation. Pickup from an extraneous field will cause error in phase indication, and it may also produce nonlinearity in current indication; therefore current indications will be in error when a change of operating conditions occurs.

c. Use of the RCA Sampling Kit MI-8217

In general, electrostatic shielding is essential to assure stability and accurate indications. In the RCA Sampling Kit (MI-8217), no provision need be made for electrostatic shielding since each sampling coil is constructed with an internal double electrostatic shield. If the sampling equipment is to be located within a tuning house, a shield compartment as outlined in Fig. A-11 can be constructed of copper or copper-lined steel. For outdoor locations, the enclosure can be weatherproofed by the use of Type 306 5-3/8″ ceramic bowl insulators for powers up to 5 kilowatts and for radiators whose operating impedances are less than approximately 200 ohms at the sampling point. For higher power, larger insulators should be employed. For 50-kilowatt installations, where the radiator is sampled at a point of high impedance, the clearance of the sampling coil from the antenna bus should be increased an additional inch to prevent voltage breakdown.

In operation, the sampling coil should be carefully tuned to the transmitter frequency. For frequencies above approximately 1000 kc, L1 and C1 will tune to resonance. Below 1000 kc, a fixed capacitor (Faradon Model "NF") should be connected in paralled with C1 (across terminals 2 and 3). The values for this capacitor for several frequencies ranging downward from 1000 kc, are given below:

100 μμf to 800 kc
200 μμf to 650 kc
300 μμf to 600 kc
400 μμf to 550 kc

A thermogalvanometer connected across terminals 1 and 2 makes an excellent resonance indicator. The coil should be loosely coupled to the antenna lead or to one of the low power stages of the transmitter, and C1 adjusted for maximum current indication and then locked securely in place. Any appreciable deviation from true resonance will introduce error in measurements (Paragraph 1a).

For satisfactory results, care must be taken in the placement of the pickup coil. A position should be chosen to eliminate magnetic coupling to all sources except the one which is to be measured. If more than one antenna element is to be monitored, all coils should be placed in the same relative physical location with respect to the antenna leads to which they are coupled, otherwise an 180-degree error may be introduced. A suggestion for mounting the sampling coil is given in Fig. A-11, which shows the position for maximum coupling. Pickup may be reduced by slightly rotating the coil assembly in the horizontal plane.

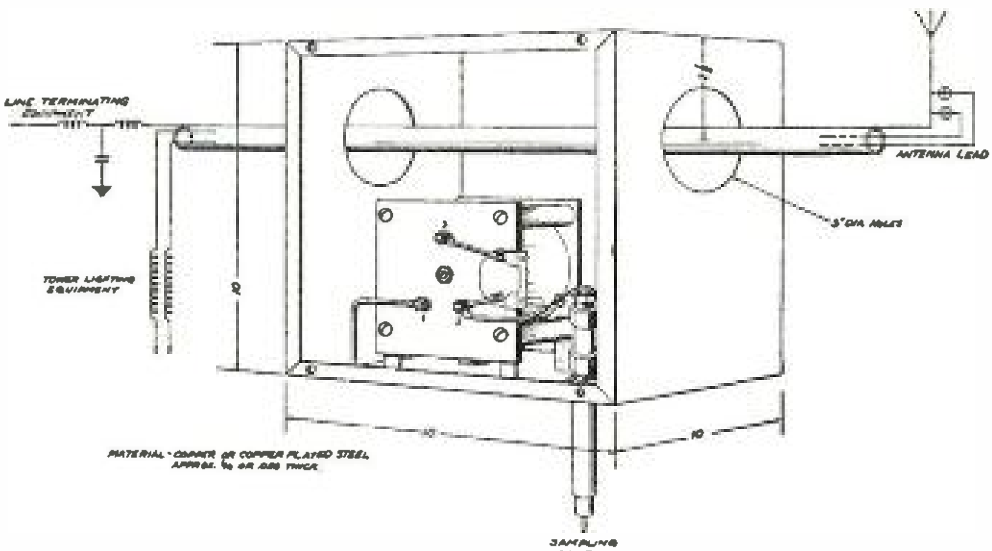

Fig. A-11. Suggestion for housing the sampling coil, showing the position for maximum coupling.

Ninety degrees of rotation reduces the induced voltage to essentially zero. In cases where the current in the antenna lead is too low to give sufficient output voltage from the coil, the spacing between the coil and the antenna lead may be decreased to increase the output. But in no case should the clearance be less than one inch, in order that danger from voltage surges be minimized. In extreme cases the antenna lead can be formed into a single turn loop parallel to the turns of the pickup coil, and the spacing reduced to approximately one inch.

so that the pointer deflection on the scale of the antenna-current indicator is identical to that for the respective antenna ammeter. This is described in section 3.

The sampling line can be any one of a number of types of concentric lines with surge impedances from approximately 50 to 100 ohms. In general, open-wire lines prove unsatisfactory; if used in the vicinity of the antenna, objectionable currents will be induced in the lines. The beaded coaxial line is an entirely satisfactory type for sampling. This type line can be obtained with surge impedances ranging from 72 to 150 ohms. Its construction provides an efficient, low-loss transfer of energy and makes it suitable for long periods of outdoor use. An ideal sampling line installation would be the use of beaded coaxial line installed within gas-filled copper tubing. Such a line could be depended upon to give reliable service over long periods of time. Solid-dielectric coaxial lines have been developed which should give long trouble-free service. They require no pressurizing.

In order that no phase shift is introduced in the sampling system, particularly if a phase meter is used, each sampling line must be terminated in its characteristic impedance, which is nominally 79 ohms for ¼ inch concentric line. The terminating networks for each line on the RCA WM-30A Phase Monitor and in the Remote Antenna-Current Indicator are identical, except that when the two units are used together the input impedance of the Phase Monitor, an effective 2000 ohms, is shunted across the output of the Remote Antenna-Current Indicator as shown in Fig. A-9. This should be considered when calculating the correct value for the plug-in resistors (R4, R5, and R6) of the Remote Antenna-Current Indicator. For example, assuming that a transmission line of 70 ohms impedance is used, then the value of plug-in resistor (R) can be determined as 68 ohms by using the formula for d-c resistance:

$$Z_{input} = R_m + \frac{R_s R}{R + R_s}$$

where: Z_{input} = desired input resistance

R_m = resistance of the meter and its shunt (4 ohms)

R_s = shunt resistance of Phase Monitor (2000 ohms)

Using these values and solving for R:

$$R = \frac{2000\,Z - 8000}{2004 - Z}$$

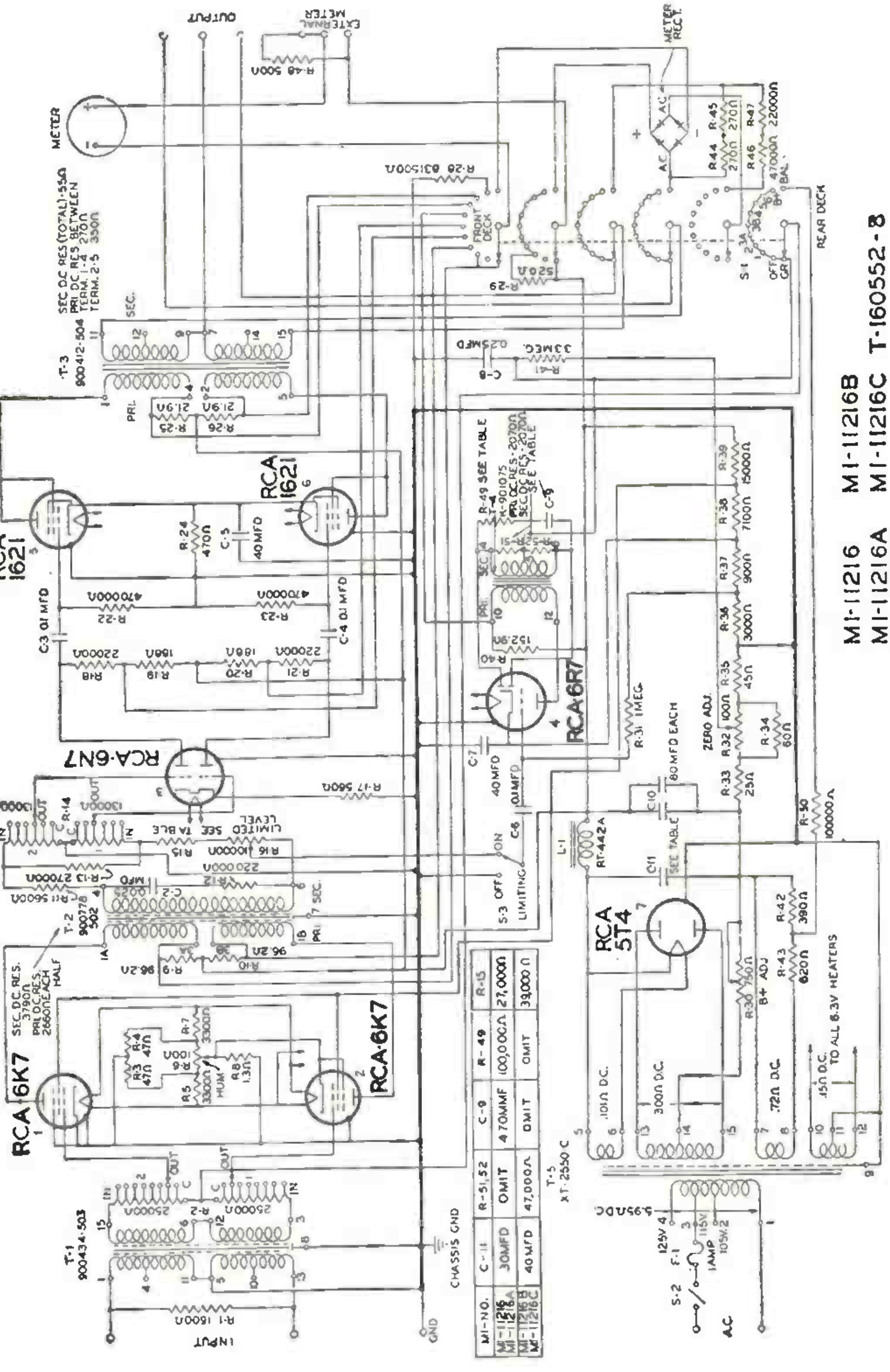

Fig. A-15. Schematic diagram of the limiting amplifier.

As previously stated, an exact line match is unnecessary. Except at critical line lengths, variations of as much as ten percent from the correct load value will introduce no appreciable error in either current or phase indication. Whether any error is being introduced by the Remote Antenna-Current Indicator can be determined by eliminating the unit from the circuit and calibrating the Phase Monitor. Any existing error will then be indicated by the Phase Monitor when the Remote Antenna-Current Indicator is again inserted into the circuit.

RCA LIMITING AMPLIFIER

Application

The Type 86-A1 Limiting Amplifier is intended for use in the speech input channel of a radio transmitter to prevent overmodulation by limiting the high audio signal peaks which occasionally occur in program material. This limitation permits a substantial increase in the average level of modulation, and hence an increase in the effective range of the transmitter without any increase in carrier power. The amplifier may also be used advantageously in recording.

Action of Limiter

The action of the limiter is similar to that of delayed automatic volume control in a radio receiver. For signal levels below a specified value, the gain in the amplifier is not affected. Above this level, however, the gain is sharply reduced, and the amount of reduction increases with the strength of the signal. As a result, above the predetermined level the output of the amplifier changes relatively little for large changes in the input level. The electrical action of the limiter is shown in the circuit diagram of the amplifier (Fig. A-15). A portion of the signal voltage across the secondary of T-2 is impressed on the grid of the triode section of 6R7, and the resulting output of this triode is then rectified by the two diodes of the same tube. The diode plates are polarized negatively by a fixed amount so that the diodes do not conduct until the signal voltage exceeds the polarizing voltage.

Adjustment Controls

Several minor controls are provided in the amplifier for facilitating restoration of balance in the circuit after tubes and other parts have been replaced. These controls are taken up below.

a. *Limited Level.* The control marked LIMITED LEVEL on the chassis and R-16 in the circuit diagram permits variation of the input voltage to the control tube 6R7 when the limiting switch S-3 is in the ON position, and in this manner allows variation in the degree of limiting. The range of variation is from about 73% to 90% of the total signal voltage across the secondary of transformer T-2. The adjustment is effected with a screw driver through the door in the panel. The use of this control is discussed under Maintenance.

b. *Zero Adjustment.* The control marked ZERO ADJ. is a 100-ohm potentiometer R-32 in the low potential side of the voltage divider of the power supply. This is also adjusted with a screw driver and is reached through the door in the panel. It serves to adjust the reading of the gain reduction meter to 0 db when the amplifier is not limiting. Its adjustment is discussed under Maintenance.

c. *Hum Adjustment.* This control is a 100-ohm potentiometer R-6 in the cathode-heater circuit of the 6K7 tubes which serves to reduce the hum to a minimum. It is reached through the door in the panel and is adjusted with a screw driver. For further details refer to *Hum Reduction* in Maintenance.

d. *Power Switch and Fuse.* The power switch S-2 and the fuse F-1 are located at the right end of the chassis just inside the door in the panel. When the signal is strong enough to make the diodes conduct, capacitor C-8 charges up to a voltage which depends on the amount by which the signal voltage exceeds the polarization voltage. The voltage across the capacitor is then applied as bias on the control grids of the two 6K7 tubes. The higher this bias, the less these tubes amplify. Thus an automatic check on the gain in the amplifier is established as soon as the signal voltage exceeds a predetermined value. The effectiveness of the limiting, for one particular setting of the controls, is shown in Fig. A-16.

Time Constants

If overmodulation of the transmitter is to be prevented when sudden intense peaks of signal occur, the limiter circuit must respond almost instantaneously. This requires that capacitor C-8 be charged through a low resistance and that its capacity be not excessively large. The specified capacity of C-8 is 0.25 μf and the resistance of the charge circuit is virtually only that of the diodes. This combination is such that the circuit responds in about 0.001 second, which is generally considered fast enough.

After the gain has been depressed by a sudden strong peak, the circuit must recover its normal amplification if signals of weak and moderate levels are to reach the modulator with desired amplitudes. This limiter recovers by the discharge of C-8 through resistor R-41. For the specified values of C-8 and R-41 it requires about 2 seconds for the circuit to recover 90% of its normal gain. A longer recovery

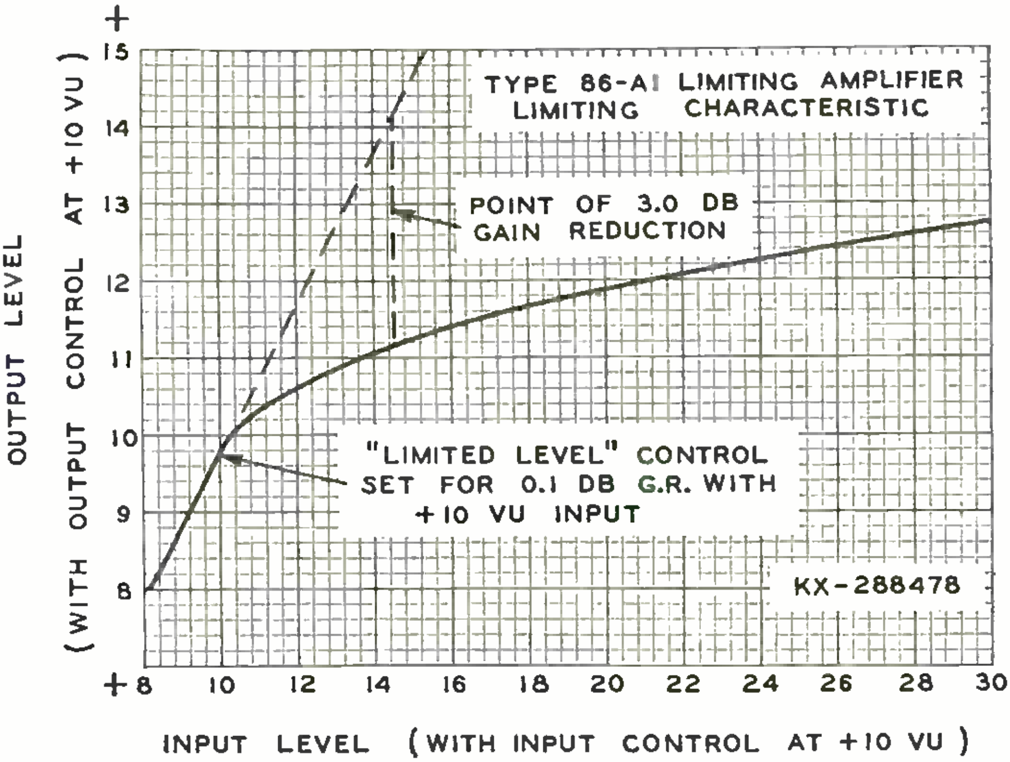

Fig. A-16. Effectiveness of limiting action performed by the limiting amplifier.

time would cause noticeable loss of volume after each gain reduction, and a much shorter recovery time might have an unfavorable effect on the quality.

Amplifier Connections

Make all permanent connections of the amplifier to the terminal board located at the rear of the amplifier.

a. *Input Connections.* The incoming signal line should be connected to the terminals marked INPUT on the rear terminal board. These terminals connect to terminals 1 and 13 on transformer T-1. With this connection the input impedance is 500-600 ohms and therefore the source impedance should have this value. If the source impedance is 250 ohms, the input leads should be moved from terminals 1 and 13 to terminals 4 and 10, respectively, leaving the connection of R-1 undisturbed. The input leads should consist of shielded and twisted pair insulated for 200 volts. They should be kept away from all other leads as much as practicable. In making connections to the source of signal it should be remembered that the center of the input transformer T-1 is connected to chassis ground.

b. *Output Connections.* The load on the amplifier is connected to the three terminals marked OUTPUT. When the load impedance is 500-600 ohms, the two output leads (brown and black-brown) should be left connected to the secondary of the output transformer T-3. But if the load impedance is 250-300 ohms, the two outside leads should be moved, respectively, from terminals 11 and 15 to terminals 12 and 14 on the output transformer. The middle of the three OUTPUT terminals is connected to the mid-point on the secondary of the transformer. When this impedance change is made, the two resistors R-45 and R-47 in the meter rectifier circuit should be short-circuited.

The output leads, like the input leads, should be shielded and twisted pair insulated for 200 volts, and they need not be larger than No. 19 A.W.G. They should preferably go directly to the transmitter.

c. *External Meter.* Provision has been made for the use of an external gain reduction meter. In installing this meter, the shunt on the terminals marked METER should be removed and the meter should be connected to the terminals directly above the marking. The center terminal is negative.

Setting Up

After the input, output, and power connections have been made to the amplifier, set the input and output controls to the approximate levels to be used. Turn the meter switch to GR and impress a 200- to 2000-cycle sine-wave signal of constant amplitude on the amplifier. Use the LIMITED LEVEL control as a vernier on the OUTPUT CONTROL to obtain the exact maximum modulator input level when the meter shows a gain reduction of approximately 3 db. If the LIMITED LEVEL control does not have sufficient range to bring this about, readjust the input by the required amount. When this adjustment has been effected, the gain reduction in the amplifier is determined by the input signal level and by the setting of the INPUT control, as well as by the dynamic range and character of the signal material. The INPUT control provides for changes in 2 db steps. If the program limiting requires closer adjustment, it should be done with a continuous control in the channel preceding the Type 86-A1 amplifier.

The average reduction should not exceed about 3 db. This corresponds to a condition in which the meter needle normally stands at or near 0 db gain reduction and only intermittently kicks to 3 db gain reduction. In estimating the momentary gain reduction it should be remembered that the meter needle tends to overshoot slightly. When the system has been adjusted in this manner, momentary overmodulation may occur on strong signal peaks. However, the periods of overmodulation will be exceedingly short and will not give rise to noticeable distortion or interference with other channels. They will occur during the initial period of a gain reduction and during periods of rapid change in the signal level.

Adjustment for Line Voltage

The Type 86-A1 amplifier has been wired at the factory for a power line voltage of 115 volts. If the line voltage regularly deviates from this value by more than 5% in either direction, an appropriate wiring change should be made in the primary of the power transformer T-5 (Fig. A-15). The lead containing the fuse should be moved to tap 4 if the line voltage is high and to tap 2 if it is low.

MAINTENANCE

If the Type 86-A1 amplifier is to give top performance at all times, it must be maintained in good operating condition. It should be tested frequently and be subjected to such corrective measures as the tests indicate. In order to facilitate these tests, the meter switch has been provided. With it the indicating meter can be connected into eleven different points in the circuit. The quantity measured in each position and the result expected are shown in the table below.

Adjustments

If the indications are not as expected, adjustments must be made to bring the circuit in balance. These adjustments may be required because tubes have been replaced, because the old tubes have deteriorated unequally, or because of some other change in the circuit.

a. *Plate Voltage.* If the readings are consistently either above or below the CHECK mark, it is likely that the plate voltage is at fault. A check on step B+ will disclose whether the voltage is high or low. If an adjustment must be made, turn the control marked B+ ADJ.,

Dial	Indication	Meter Range
GR	Gain reduction	DB Scale
OFF	Meter disconnected	
1	Ip of RCA-6K7 No. 1	Check
2	Ip of RCA-6K7 No. 2	Check
3A	Ip of RCA-6N7 No. 3	Check*
3B	Ip of RCA-6N7 No. 3	Check*
4	Ip of RCA-6R7 No. 4	Check
5	Ip of RCA-1621 No. 5	Check*
6	Ip of RCA-1621 No. 6	Check*
BAL	RCA-6K7 balance	6K7 Match
B+	Rectified output voltage	Check

* NOTE: Readings on 3A and 3B should be in the check range, but they may be between 1 and 4 on the meter scale provided that the two readings do not differ from each other by more than the width of the check range mark. The same applies to the readings on steps 5 and 6 for the two RCA-1621 tubes.

which is the 750-ohm rheostat R-30 in the lead from the center point on the secondary of transformer T-5, until the voltage reading checks.

b. *Zero Adjustment.* Turn the meter to GR. Do not impress an input signal on the amplifier. Adjust the ZERO ADJ. control R-32 until the meter indicates 0 db gain reduction. Make the adjustment slowly so that the meter will have time to come to rest after a change in the adjustment has been made. This precaution is necessary because of the long time constant of the reduction circuit on recovery.

c. *Hum Reduction.* Connect a 600-ohm resistor across the input terminals in place of the signal source and connect the output terminals of the amplifier to the input terminals of a Type 69-B Noise Level Meter. Set the input and output controls to the positions used in normal operation and adjust potentiometer R-6, marked HUM on the chassis, until the hum is minimum.

d. *Dynamic Balance of 6K7's.* Turn the tubes on and let them warm up for about 10 minutes. Set the meter switch on BAL. This injects a 60-cycle voltage into the control grids of the 6K7's, with the grids in parallel, and it also connects the 60-cycle output of the amplifier, through the rectifier, to the indicator meter. Set the OUTPUT control to +30 db, that is, to the point of greatest output. This output will be due to unbalance in the amplifier. The meter indication should fall within the 6K7 MATCH range of the scale. If it falls outside, other pairs of 6K7 tubes should be tried until the match is close enough to bring the needle within the match range.

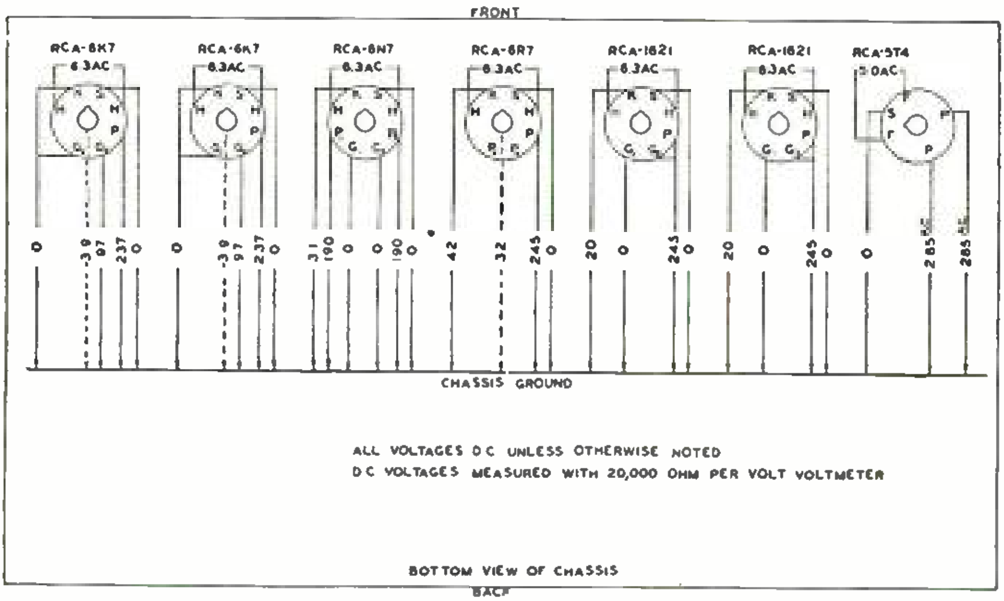

Fig. A-17. Operating voltage chart for the limiting amplifier.

e. *Limited Level.* A change of tubes may result in a slight change of gain in the amplifier, or a change in the level at which gain reduction starts, or a change in the level to which the output is limited. Therefore the LIMITED LEVEL control should be readjusted whenever tubes have been changed. When this control is in mid-position, the INPUT control calibration shows the approximate level at which limiting action starts, and the OUTPUT control calibration shows the approximate level at verge of limiting. The LIMITED LEVEL control changes both these calibrations over a range of about 1.5 db. In setting this control, the limiting switch should be set to ON and the meter switch to GR.

Operating Voltages

The normal operating voltages, a.c. as well as d.c., are shown in Fig. A-17. These voltages should be obtained when the a-c line voltage is 115 volts and the d-c voltages are measured with a 20,000 ohms per volt meter. Measured values should not differ by more than 5% from the listed values. If the d-c voltages are measured with a voltmeter having a lower resistance, all readings will be less than those listed by an amount depending on the resistance through which the meter current has to flow. The voltage across capacitor C-11 should be about 280 volts.

Time Constant Changes

Occasionally after the amplifier has limited a strong peak in the program or a sharp transient in the input line, a blank in the output may be observed. That is, a note of music or a word of speech may be missing. This lapse is due to the slow recovery rate of the gain in the amplifier. While such lapses are normal, their observance is rare. If, however, they should be observed so frequently as to become annoying, it may be desirable to change the time constant of the recovery circuit. This is done simply by changing the value of resistance R-41. The table below gives the time constants for five different values of R-41 and the resulting time of gain recovery.

R-41	*Time Constant*	*Time for 50% Recovery*	*Time for 90% Recovery*
10 meg.	2.5	1.4 sec.	5.2 sec.
5 meg.	1.25	.7 sec.	2.6 sec.
2.5 meg.	.625	.35 sec.	1.3 sec.
1.25 meg.	.313	.18 sec.	.65 sec.
.5 meg.	.125	.07 sec.	.26 sec.

As an aid in the selection of time constant for gain recovery the following facts are presented:

a. *Fast Recovery Rate*

(1) Smaller loss of low-amplitude passages which follow soon after passages which are higher than the critical level. This is not serious if high values of compression are avoided, as they should be.

(2) More readily obtainable in design.

b. *Slow Recovery Rate*

(1) More thorough filtering of the control voltage is obtained. That is, the control voltage has less tendency to swing with individual audio cycles and thus less distortion is introduced.

(2) Any background noise returns more slowly after removal of a signal higher than the critical value, and thus is less noticeable.

(3) Other factors and adjustments being the same, on average programs there is less loss of dynamic range.

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About the Author

Harold E. Ennes—a staff engineer at Station WIRE in Indianapolis, Ind.—has been connected with many phases of radio engineering since 1930 and this experience of a practical nature along with his ability to choose and explain subjects needed by every man behind the scene in a broadcast station, makes an ideal combination.

Ennes received his broadcast training at the old First National Television station of Kansas City, Mo., which operated the experimental high-fidelity station W9XBY and the experimental television station W9XAL, obtaining his First Class Radiotelephone license in 1936. He joined the engineering staff of WIRE in that year and has been with that station ever since.

Early in his radio engineering career, Mr. Ennes became conscious of the dearth of literature concerning the technique of operating procedure, which was learned the hard way—by experience on the job. It was a desire to get operating facts on paper that led him to learn all he could about operations and special problems in stations of all sizes, interviewing engineers and operators in stations in many different parts of the country.

While this is Mr. Ennes' first full-length book on the technical aspects of putting programs on the air, he has contributed many articles on this and allied subjects to the radio press. In short, he has been endeavoring for the past few years to give to the industry the kind of data he would have liked to have had available when he was a newcomer in the field.