Western Electric
OSCILLATOR

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Loudspeakers for the New Era in Sound Reproduction

Western Electric
OSCILLATOR

JULY 1947

DEVOTED TO DEVELOPMENTS IN COMMUNICATIONS AND ELECTRONICS

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THE COVER

By "going out on the wire" in the new dead room at Murray Hill to set up a test on the 757A Loudspeaker, Bell Telephone Laboratories Engineers L. Vieth and H. F. Hopkins produced the startling floating-in-air effect that Nickolas Muray caught in this month's color photograph. This new "free field" chamber for testing electro-acoustic devices is described technically in the article on page 39 of this issue. The characteristics of the room are startling to the engineer, with its virtually complete absorption of sound down to very low frequencies. The five-foot long wedge-shaped projections of sound absorbing material cover the entire area of walls, ceiling and floor with their strange pattern of squares. The wire mesh used as a platform for equipment under test is "transparent" to sight as well as sound, and enables workers in the room to float ten feet above the floor with a mere suggestion of support. Science is sometimes dramatic — even outside of fiction.

THIS ISSUE

The Curtain Rises on a New Era in Sound

It's high time we interred an old story that has been going the rounds for years. It has hindered progress and the thinking of too many people for too long. You know the story. It's to the effect that the tone controls on radio sets displayed in retail stores are always found in the bass position. The inference, of course, is that the public, which likes to turn dials, also prefers plenty of bass and no high notes.

That might have been true in the early days but it just isn't true today. And if any set manufacturer finds it true of his product, he'd better raise his eyebrows at his radio, rather than at the public's taste in sound.

We know there are many people who still firmly believe that the public doesn't go for high quality in sound reproduction, but they are the misguided ones, not the public. People, of course, do like what they are accustomed to, and when something better is offered them, it takes time for them to accept the new. That goes for almost anything, and it goes double for sound reproduction.

We have been through this so many times before, the public reaction to improvement in sound can now be charted with almost scientific accuracy. Remember the early days of sound pictures? Certainly no one complained that the quality was too good. The frequency range was narrow and accompanied by quite an assortment of noises and a high over-all noise level. But when such improvements as noiseless recording and wide range recording and reproduction were introduced, it did take time for the public to become accustomed to the better sound. Soon, however, they did become accustomed to it, and no one can be found today who would welcome a return to the earlier quality of sound in motion pictures.

The experience of the motion picture is typical of all phases of sound reproduction. There may be a short time-lag in the popular acceptance in the quality of sound, but each improvement does become accepted and when it is, a distinct gain is made—a net gain which can never be lost.

This is so true it is easily demonstrable. All one has to do is to let people hear a talking picture of 10 or 15 years ago, or a radio receiver of similar age. The immediate reaction becomes, "How on earth did we ever listen to that and like it?"

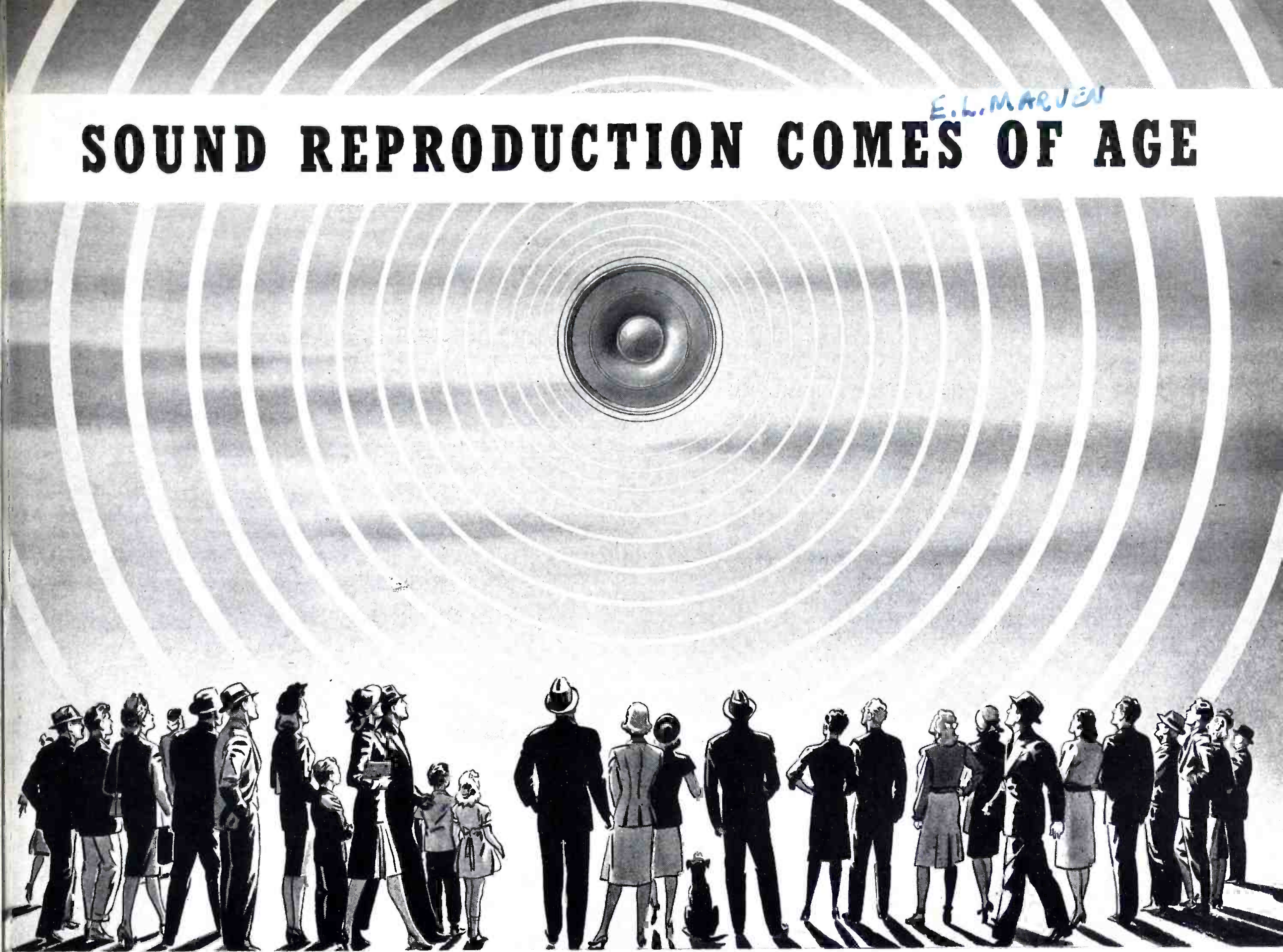
So let's forget any ideas that we might have had that the public will not appreciate or pay for higher quality in sound reproduction. Let's just remember that every improvement in sound quality in the past has been accepted by the public and that the public is ready for more. Let's remember, too, that there have been instances where the public refused to accept what appeared to be increases in the frequency range of sound reproduction. We know now, however, that such failures were due to the fact that so much more noise and, in particular, distortion were added that the public was quite right in refusing to accept this so-called "high quality" sound.

Much has been learned in recent years and tremendous progress has been made in technique and instrumentation. Today high quality sound with noise and distortion reduced to a minimum is possible and practicable. We have the equipment, we know the techniques.

With this knowledge and with the instrumentation, we are due to see the whole art of sound reproduction take on new significance, new acceptance and stature. The curtain is rising on a new era in sound.

W.W.

SOUND REPRODUCTION COMES OF AGE



By E. M. Hall

Manager, Sound Systems and Communications
Radio Division, Western Electric

EVERY worker in the art of the reproduction of sound today can find a new pride, a powerful incentive in a full understanding of the significance and importance of his art. For the recording, transmission and re-creation of sound have reached a level of technical maturity making sound reproduction a major influence in our society, and opening wide horizons to further extension of its influence and scope.

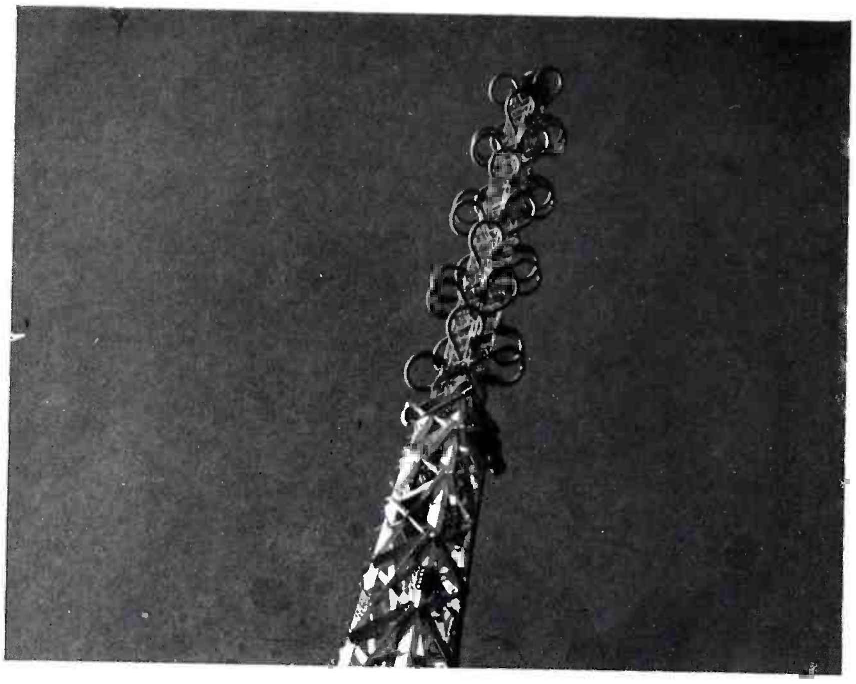
The functions of reproduced sound have become matters of tremendous weight and import. The millions of telephone calls made in a day are the vast nerveflow of our most vital individual communications. The eighty million people who sit in darkened theatres every week, while the vibrating diaphragms in back of the screen recreate the sound of the drama, are engaged in a process of entertainment and education that is profoundly influencing our social system. The thirty million radio loudspeakers in American living rooms link nearly every home in the country into a second universal system of entertainment and information, staggering in its political and cultural importance. Either the radio or the movies alone could be considered as the most powerful, all-reaching technique of mass communication in the history of the world. Both of them are now part of the fabric of American life, putting the reproduction of sound in a position of influence such as no other technique enjoys.

Sound in Modern Life

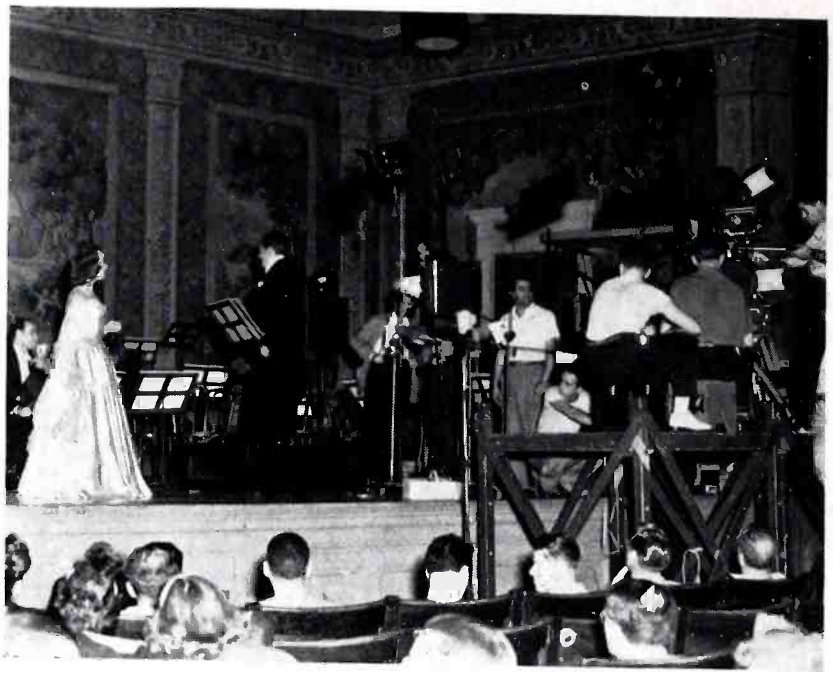
The radio and the movies are the great mass conquests of the reproduction of sound; the telephone is its universal field of service to the individual. Not far behind these three in scope and effect are a number of other applications which show not only the power but also the versatility of sound reproduction:

Recorded Music in the Home: The American people bought over 300,000,000 phonograph records in the *one year 1946*. The indications are strong that with phonograph equipment becoming readily available, this figure will be even greater in 1947. Such a mass of music, personally selected and instantly reproducible at any time, is another new and very big thing in our cultural history. It is a major part of, as well as one of the chief causes of, the great upsurge in musical taste that has made recordings for the home "big business." The enjoyment of music that these hundreds of millions of phonograph records represent, measured either on statistical or esthetic planes, would not have been dreamed of before the recording and reproduction of sound became a flexible, effective technique.

The Orator and the Mass Meeting: As everyone knows, the day is long past when the political orator depended on the power of his lungs to sway crowds of people. The reach of the spellbinder can now be made as great as any mass of people that can be assembled, no matter how vast. And the



FM RADIO: Opening a new era in broadcasting quality, FM — symbolized by this modern antenna — demands a higher fidelity in sound reproducing equipment.



TELEVISION: Another new field of sound reproduction. Coordination with sight requires that there be an increase in the naturalness of reproduced sound.

revolution is not only in the size of great political gatherings but in their power and ability to rouse mass emotions.

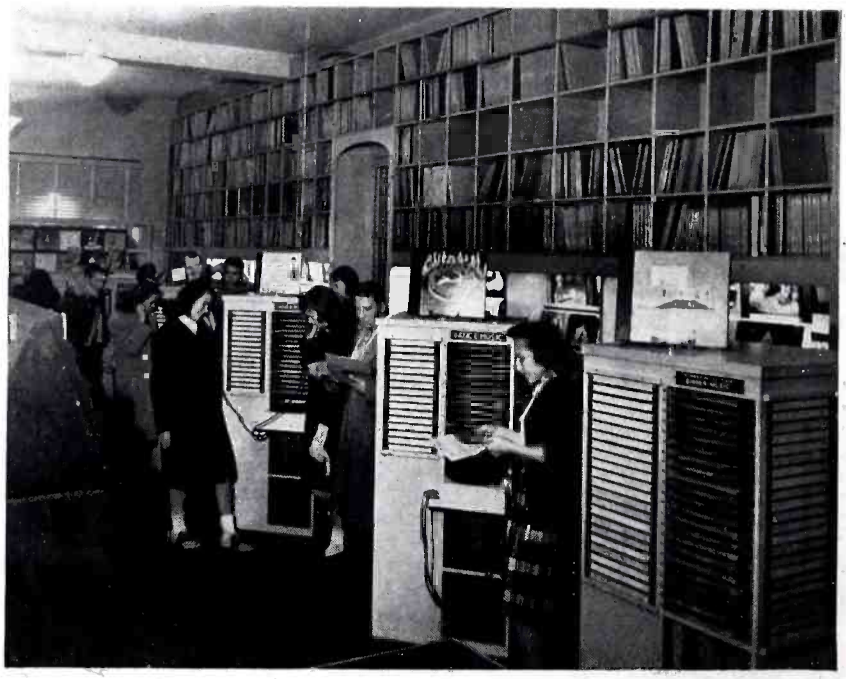
The Circus Barker, The Historical Pageant, The World's Fair: "Public address" now serves a multitude of places, events and persons. It is the indispensable tool of the circus barker, the auctioneer, the charity campaigner, the commencement valedictorian, the night club entertainer—and an endless number more. We can go to scarcely any public function of information or entertainment today that does not use it for greater effectiveness. At another level, outdoor sound serves as a necessary part of the large-scale pageants that dramatize inspiring passages in our history. When Washington Crosses the Delaware or the Conestoga Wagons Roll Westward on the stage of an American amphitheatre, the music and spoken drama that bring the whole production to life depend on the loudspeakers mounted in back of the scene. And the World's Fair! The ingenious spectacles which marry engineering and art in the cause of public instruction and amazement at our great Fairs would not be possible without reproduced sound.

Centralized Intelligence in Public Buildings and Outdoor Arenas: In public buildings of every kind such as hospitals, hotels, railway stations, etc., it is now accepted as commonplace that every part of the area should be linked by loudspeaker systems to a central position for announcements or paging. The sports event would be incomplete without high level sound projection to introduce the sequence of events.

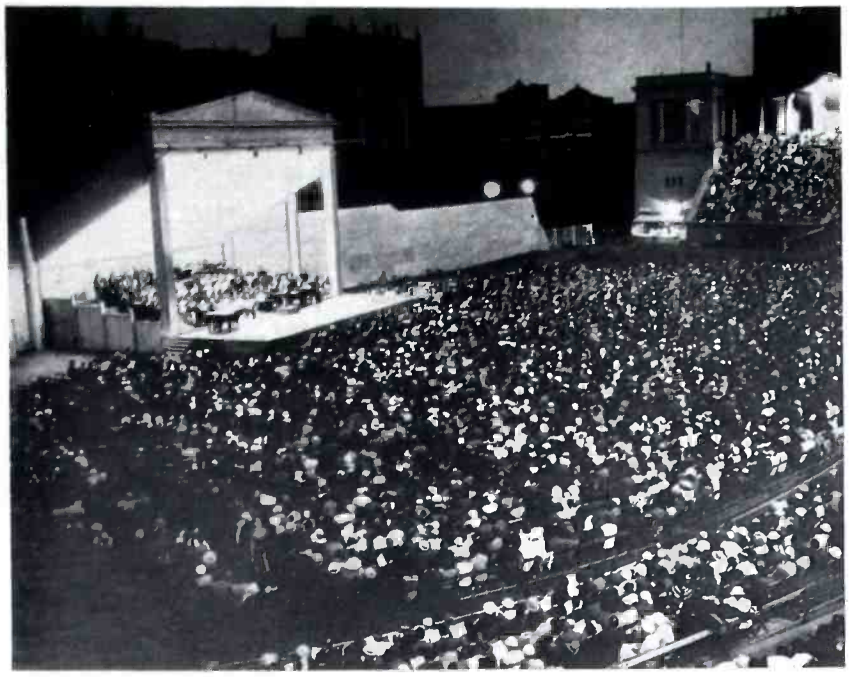
Making the Symphony Orchestra Larger than Life: Music can now take command in areas far larger than the traditional concert hall. It can be heard in the open air "under the stars", in parks or other settings of natural beauty, at the volume necessary for full emotional participation and with that additional pleasure of having the musicians actually at work in front of the audience. Such "magnified concerts" now reach millions and millions of Americans every summer, with the great upsurge of musical interest to send them in search of this new pleasure. Within the concert hall itself, volume reinforcement is becoming an important technique, overcoming the traditional deficiencies of the hall, adding flexibility to the choice of music and greatly increasing the pleasure of the listener.

Musical Stimulus and Entertainment for the Worker: Background music as a work

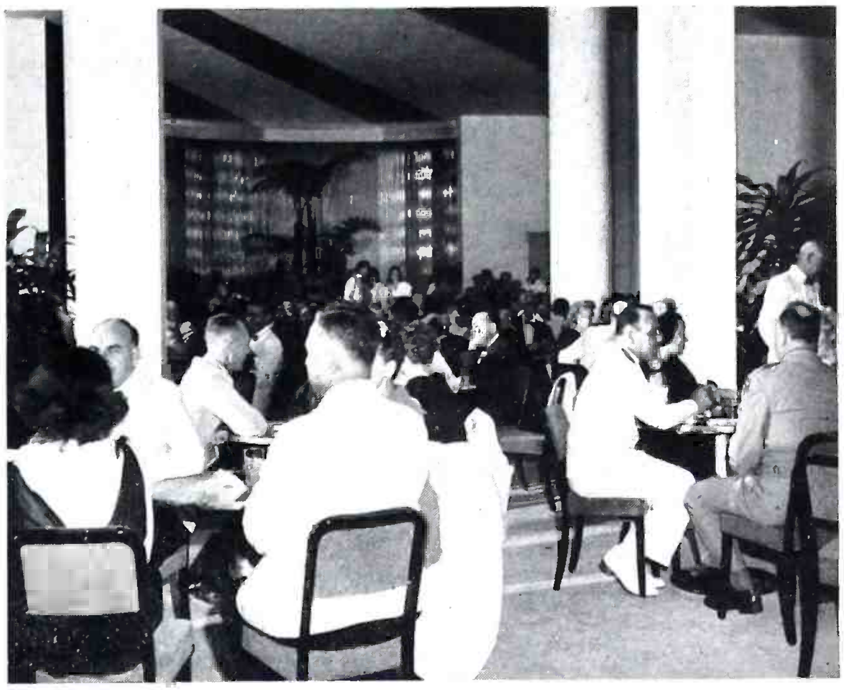
MOTION PICTURES: One of the great mass communications fields. Improvement in sound makes possible such outstanding music as in the film "Carnegie Hall."



RECORDED MUSIC: To millions of people, vast improvement in recording has meant the pleasure of "purchasing" great music that is faithfully preserved.



SOUND REINFORCEMENT: Vast strides in early public address systems have brought new beauty of sound reproduction to outdoor concerts and public halls.



BACKGROUND MUSIC: The country's finest hotels and restaurants now offer relaxing music — reproduced and distributed for the pleasure of their customers.

stimulant, a morale builder, or purely as entertainment, has won a spectacular acceptance in factories, offices and other places where numbers of people do monotonous or repetitive work. It is estimated that in the last two years more than five million people were working with some kind of musical background to aid them. With proper handling of both technical and esthetic phases of such systems, the worker finds his boredom and tension reduced, his spirits lightened, his abilities quickened.

And this field has much greater usefulness ahead of it. The need for expert understanding of the effects of music on the psychology and physiology of the listener has opened up a new field of investigation, one with great promise for developing new facts on the basic values of music.

Music to Make the Customer and the Traveler Happy: Reproduced music as a background, an added "service" to increase the pleasure and good will of the customer in hotels, restaurants, stores, etc., is a well-established idea, but its application is growing and spreading as fast as equipment can be bought and installed. The night club or restaurant patron is aided toward that relaxed frame of mind which goes with success and continued patronage in such establishments: the store customer finds his surroundings attractive, and lingers. A new field for such installations—program distribution on common carriers—is about to become a major application of reproduced sound, as the various forms of transportation prepare to battle for the traveler's dollar. Loudspeakers are being installed over train seats, in staterooms and on the decks of ships, in the seating compartments of planes. Soon it will be usual for the traveler on a far journey to have music to fill in the long, empty hours.

The Coin-Operated Phonograph: The "juke box", almost as old as the reproduction of sound itself, has a special place of its own in our economy and our affection. It is a necessary part of growing up in small-town and suburban America, and a two-hundred-million-dollar-a-year part of the distribution system for "popular" music, the ballads, the love songs, the dance tunes to which young America listens. The ice cream parlor, the corner "coke joint", and lately the teen-age entertainment center all need nickel-in-the-slot music in order to perform their important social functions.

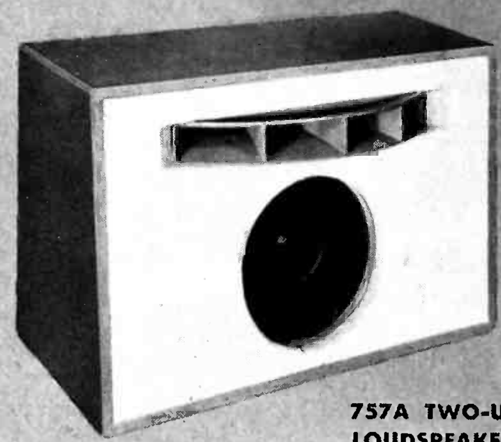
(Continued on page 31)

PROGRAMS FOR TRAVELERS: Sound enters another new field! Soon reproduced music and radio programs will be distributed throughout trains, planes, ships.

MUSIC FOR WORK AND PLAY: In factories, offices, homes, schools, drugstores and dance halls, this new enjoyment is a part of our everyday life.

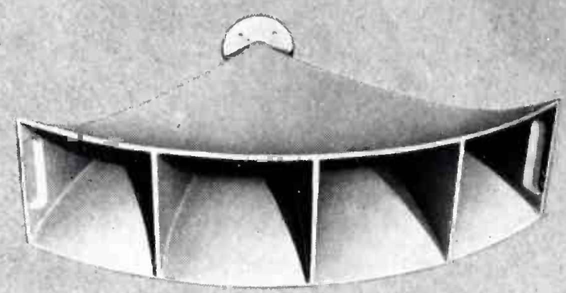
QUALITY

728B 12-INCH
DIRECT RADIATOR

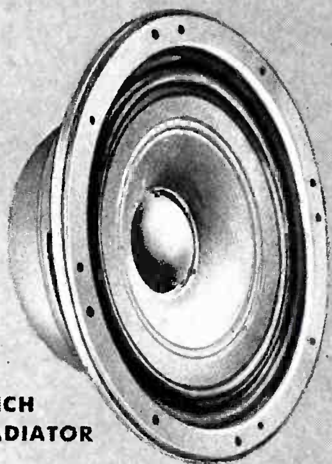


757A TWO-UNIT
LOUDSPEAKER

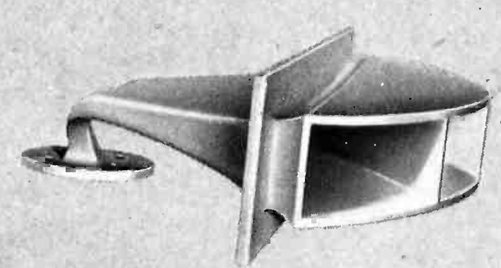
756A 10-INCH
DIRECT RADIATOR



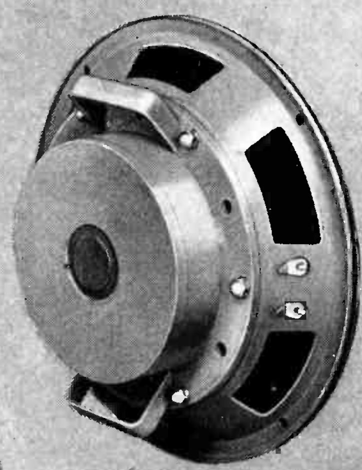
KS-12025 HORN



755A 8-INCH
DIRECT RADIATOR

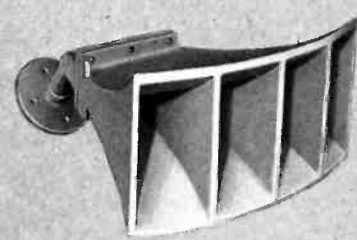


KS-12027 HORN



754A AND 754B
12-INCH DIRECT RADIATORS

HIGH LEVEL
LOUDSPEAKER SYSTEMS



KS-12024 HORN

713B AND 713C
HIGH FREQUENCY RECEIVERS

LOUDSPEAKERS FOR EVERY USE

Western Electric's New Line Covers Every Loudspeaker Need, from the Radio Receiver Using 8 Watts to Amphitheatre Systems Using Hundreds of Watts of Power

By Frank Nickel

Radio Division, Western Electric

THE industry now has available an entire line of loudspeakers, each providing the high quality, full range, distortion-free sound that has made such a powerful impression for Western Electric's new 728B speaker—this is the important and practical meaning of Western Electric's new loudspeakers now in production. These new speakers have been designed by Bell Telephone Laboratories so that truly high quality sound can be enjoyed wherever reproduced sound is used, from the radio receiver in the moderate-sized living room, to the outdoor amphitheatre system using hundreds of watts of power to carry music and speech to thousands of listeners.

The following article describes the *application* of these speakers in the various fields of sound reproduction, showing how they are to be *used*—the choice of the proper mechanical and electrical characteristics for each installation. Each of the major fields of sound reproduction practice is covered separately, with a description of the speakers intended for use therein. In addition, the table on pages 8-9 gives complete technical information on the entire line, so that the designer, manufacturer, or sound technician can find the speaker best suited to his needs.

The major fields of use which are covered are the following:

1. *Home Receivers for AM, FM, and Television, and Home Record Players.*
2. *Indoor and Outdoor Sound Distribution and Paging.*
3. *Wired Music and Program Distribution for Hotels, Restaurants, etc., and Public Carriers.*
4. *Broadcasting Station and Recording Studio Monitoring.*
5. *Motion Picture Theatre Sound Systems, and Portable Projectors for Sound Film.*

In the largest AM, FM and television console receivers and in custom built installations for the home, the speaker system must handle 25 to 30 watts with wide-angle distribution of distortion-free, full range sound, in an enclosure of moderate size. The table models require a speaker to handle 5 to 8 watts, which can be mounted in the smallest possible space and will still produce wide range sound of high quality, with satisfactory distribution of the high frequencies. Medium size console receivers and home record players need speakers of power capacity and space requirements intermediate to the two extremes described.

Home Receivers and Record Players

The following units in the new line meet fully the stated requirements, making possible sound projection of the highest quality in AM, FM and television receivers from the moderate sized table models to the largest consoles:

Code	Type	Diameter	Power Capacity	Frequency Response
755A	Direct Radiator	8-in.	8 watts	70 to 13,000 cps
756A	Direct Radiator	10-in.	20 watts	65 to 10,000 cps
728B	Direct Radiator	12-in.	30 watts	60 to 10,000 cps

The 755A, only 3⅛ inches deep and 8 inches in diameter, combines all of the characteristics needed in the smaller receivers of the present and future. This small edition of the 728B has built into it more loudspeaker quality and convenience than have ever before been available in a unit of this size, power and cost. The extremely small space requirements, full range frequency coverage, and wide angle distribution of high frequencies are characteristics not commonly associated with a single speaker. Added to these, of course, is the smoothness and lack of distortion that make the new loudspeakers such a pleasure for the listener.

The 756A and 728B bring the same qualities to progressively larger console receivers. Installations can be made with multiples of any of the speakers. Two of the 755A units, for example, will handle 16 watts in a space that is very small compared with the usual requirements at this power level.

Sound Distribution and Paging

This class of sound reproduction practice covers all the various forms of "public address" now encountered at every kind of meeting, sports event or lecture hall, as well as the enhancement of volume at recitals and concerts of music. The general requirements for loudspeakers in such installations are as follows:

(1) A very wide range of power levels must be handled, from 10-watt systems for small auditoriums up to public address systems with the hundreds of watts capacity needed for race tracks, stadiums, etc.

(2) Ruggedness and portability are necessary in many types of indoor and outdoor applications. Permanent outdoor installations require speakers with elements designed to withstand the weather.

(3) Volume enhancement in concert and lecture halls requires the highest quality of reproduction, to avoid distracting the listener's attention to the source of the reproduced sound and away from the speaker or musicians.

(4) Distribution patterns of various types must be provided, depending on the size and shape of the space in which the sound is projected.

The following units in the new line offer the necessary choices as to power capacity, installation requirements and other characteristics to cover fully the whole range of public address and volume reinforcement applications:

Power Capacity	Unit
Direct Radiators	
8 watts	755A
15 watts	754A
20 watts	756A
30 watts	728B
50 watts	754B
Divided Range Multiple Speaker Systems	
30 to 120 watts	High-level systems.

For portable sound distribution systems, the direct radiator types in the recommended cabinets have the convenient size, easy portability, and power capacities that make them fully adaptable to the needs of this class of service. The cabinets bring out the full quality of the speakers, but with their two to three cubic feet of volume take a minimum of space, far below the usual space for high quality speakers. If the full bass response of the speakers is not needed, they can be mounted in even smaller space. In special types of portable equipment, the direct radiator speakers can be readily installed in individual or multiple mountings of convenient dimensions as required for any application.

The 754B twelve-inch direct radiator has a phenolic cone specially designed to withstand weather conditions in outdoor installations. The speaker can be subjected to moisture and temperature variations over a wide range without affecting its performance.

For permanent high power sound distribution systems in indoor and outdoor spaces, the high-level theatre-type systems are recommended. These divided range systems have horn-type efficiency in both low and high frequency ranges, with sectoral aluminum horns provided for high frequency distribution, and low frequency horns, driven by one or more of the direct radiator types, built into the baffles which are integral with the systems. Indoor systems use the 754A; outdoor systems, the 754B, as the low frequency driver. Further details on these high-level systems can be found in the section of this article covering motion picture theatre systems.

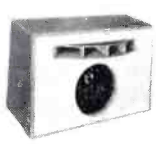
Wired Music and Program Distribution

The use of music as a business tool—a background for work or entertainment in hotels, restaurants, stores, offices, factories, etc.—is rising to new heights of popularity. During its several years of growing use, background music has abundantly proved its value in nearly every kind of business establishment and place of public entertainment. In the great majority of such installations, the most pleasing effects result from the use of a number of speakers mounted at intervals in the walls or ceiling, with each speaker furnishing sound at a relatively low level. In this way a uniform distribution of sound over the whole service area is obtained, the music reaching every listener without rising above conversational level at any point. The music has a room-filling, "sourceless" quality which interferes in no way with the business or entertainment carried on, while adding greatly to the enjoyment and pleasure of the listener.

For such multiple-speaker, background

(*Continued on page 10*)

SPECIFICATIONS OF NEW

TYPE	POWER HANDLING CAPACITY	FREQUENCY RESPONSE (cycles)	INPUT IMPEDANCE
755A 8" direct radiator 	8 watts	70-13,000	4 ohms
756A 10" direct radiator 	20 watts	65-10,000	4 ohms
728B 12" direct radiator 	30 watts	60-10,000	4 ohms
754A 12" direct radiator 	15 watts	60-10,000	4 ohms
754B 12" direct radiator (outdoor type) 	50 watts	60-10,000	4 ohms
757A 2 unit system 	30 watts	60-15,000	4 ohms
713B high frequency receiver 	25 watts	With horns KS-12024-5-7 800-10,000	4 ohms
713C high frequency receiver 	25 watts	With horns KS-12024-5-7 800-15,000	4 ohms
KS-12027 high frequency horn 	–	With 713C Receiver 800-15,000	–
KS-12024 high frequency horn 	–	With 713C Receiver 800-15,000	–
KS-12025 high frequency horn 	–	With 713C Receiver 800-15,000	–
High Level Speaker Systems (For indoor or outdoor use) 	Range from 30 to 120 watts in single units	60-10,000	Depends on Components

WESTERN ELECTRIC LOUDSPEAKERS

COVERAGE ANGLE	EFFICIENCY (Sound level at 30′ on axis)	WEIGHT	SPEAKER DIMENSIONS	ENCLOSURE REQUIRED	RECOMMENDED CABINET DIMENSIONS (Sloping front)
70°	Sound level 81.5 db above 10^{-16} watts per sq. cm. at 8 watts input	Speaker—4¾ lbs.	Dia.—8⅜″ Depth—3⅛″ Baffle Hole Dia.—7″	2 cu. ft.	Width—16″ Height—21″ Top Depth—9¼″ Bottom Depth—12″
60°	Sound level 89.5 db above 10^{-16} watts per sq. cm. at 20 watts input	Speaker—10 lbs.	Dia.—10¼″ Depth—3¼″ Baffle Hole Dia.—8 13/16″	2½ cu. ft.	Width—19″ Height—22″ Top Depth—8⅞″ Bottom Depth—11 13/16″
50°	Sound level 93.5 db above 10^{-16} watts per sq. cm. at 30 watts input	Speaker—17 lbs.	Dia.—12 11/32″ Depth—3 25/32″ Baffle Hole Dia.—11″	3 cu. ft.	Width—21″ Height—23¾″ Top Depth—9¼″ Bottom Depth—12⅜″
50°	Sound level 94 db above 10^{-16} watts per sq. cm. at 15 watts input	Speaker—17 lbs.	Dia.—12 11/32″ Depth—3¾″ Baffle Hole Dia.—11″	3 cu. ft.	—
50°	Sound level 94 db above 10^{-16} watts per sq. cm. at 50 watts input	Speaker—17 lbs.	Dia.—12 11/32″ Depth—3¾″ Baffle Hole Dia.—11″	2½ cu. ft.	—
90°	Sound level 93 db above 10^{-16} watts per sq. cm. at 30 watts input	82 lbs. including cabinet	Composed of 1-728B low frequency unit and 1-713C high frequency receiver with KS-12027 horn	Enclosure furnished with system	Width—30½″ Height—20″ Top Depth—11¼″ Bottom Depth—13¾″
(See specifications for horns)	With KS-12024—100 db KS-12025— 98 db KS-12027— 97 db	8 lbs.	Dia.—4 5/16″ Depth—4⅞″	—	—
(See specifications for horns)	With KS-12024—97 db KS-12025—95 db KS-12027—94 db	8 lbs.	Dia.—4 5/16″ Depth—4⅞″	—	—
90° horizontal 90° vertical	—	10 lbs.	Length—13½″ Width—19 5/16″ Height—2 9/16″	—	—
50° horizontal 40° vertical	—	7 lbs.	Length—16½″ Width—13 5/16″ Height—6⅜″	—	—
80° horizontal 40° vertical	—	12 lbs.	Length—19″ Width—23 21/32″ Height—6⅜″	—	—
Range from 50° to 100°	Depends on Components	Range from 140—380 lbs.	Systems composed of 754A or 754B low frequency units, 713B high frequency receivers, and KS-12024 or KS-12025 horns	Enclosures furnished with systems. Include low frequency horns	Range from 50″ x 26″ x 48″ to 78″ x 52″ x 48″

Quality Loudspeakers

(Continued from page 8)

music installations, the new direct radiator speakers 755A, 756A and 728B are made to order. Their convenience of installation in walls or ceiling, minimum space requirements, and wide angle sound distribution are essential characteristics. Their smooth, distortionless sound projection enhances the listener's pleasure and eliminates the conscious or unconscious ear fatigue that results from distorted, "peaked" loudspeaker performance.

Systems of this type are very readily expanded or rearranged by the simple addition or subtraction of one or more loudspeakers, using the new Western Electric autotransformers. Complicated systems of matching multiple speakers to an amplifier are eliminated with these transformers, which make the addition of speakers to a system as simple as connecting light bulbs across a power line. They allow the addition or subtraction of speakers from the circuit without upsetting the impedance of the amplifier and the remaining speakers. In addition, they make possible the selection, *at each speaker,* of the proper fraction of the amplifier power required at that location.

Program distribution in planes, trains and ships is a new but rapidly expanding phase of sound reproduction. Nearly every announcement of new common carrier equipment carries a reference to program distribution as one of the services that will be included to increase the attractiveness of that particular form of travel. An earlier issue of the *Oscillator*[1] described the Western Electric Program Distribution System which has been developed in cooperation with certain railroads to bring the pleasures of background music to the rail traveler. Similar systems for ships and for aircraft are in process of development.

The loudspeakers in the program system in a common carrier function in a manner similar to those in hotels, stores, etc. In public spaces multiple speakers are used to obtain uniform distribution of low-level sound. An additional type of distribution is also used in common carriers—the single small speaker which serves a single room or compartment, allowing the occupants choice of volume levels, or programs, on an individual basis. The listeners in one compartment must receive satisfactory service without disturbing persons in the adjoining spaces.

Obviously, weight and space factors are important in both the public car and individual space installations on trains. In aircraft, weight and space are of the greatest importance. For all of these light weight, small space applications, the 755A direct radiator speaker is perfectly adapted. Its weight of four pounds and depth of three inches permit it to be mounted in planes, trains or ships without the use of any bulky auxiliary structures.

The systems used on passenger ships approximate closely those used in hotel installations, with individually controlled speakers in the staterooms and low-level, multiple speaker distribution in the public rooms. In deck systems, with the weather a major factor, the 754B with its phenolic diaphragm is the recommended speaker.

In all the systems used to enhance the attractiveness of travel, the projection of the highest quality of sound is a major design consideration. The new Western Electric direct radiator speakers offer the kind of quality that is needed. They help to maintain listener comfort and pleasure over those long periods of semi-idleness that the carriers desire to make pleasant and attractive to the traveler.

Meets Monitoring Requirements

The aural monitoring of broadcast transmitters, both AM and FM, imposes severe requirements on a loudspeaker, as the speaker must furnish to technical personnel an exact reproduction of the signal going into the antenna, for expert judgment as to distortion, frequency balance, etc. The two-unit 757A loudspeaker system, which was described in detail in a previous issue of the *Oscillator*[2] meets in full the strictest standards for an AM or FM monitoring loudspeaker.

This woofer and tweeter system is a completely assembled unit, furnished in an integrally designed utility cabinet containing all of the components, including the 728B as the low frequency speaker, the 713C Receiver and the KS-12027 horn for 90 degree distribution of high frequency energy to 15,000 cycles, and the required dividing network and attenuator. The cabinet gives the proper acoustic backing to the speaker and takes up only a little more than four cubic feet of space overall, so that the unit can be installed in monitoring or control rooms of moderate size without encroaching on necessary working space.

If special installation requirements have to be met, as for instance the use of the studio wall or other permanent structure for mounting the monitoring loudspeaker, a system can be assembled from the high and low frequency units provided in the new line. The following characteristics are available in a "tweeter" with the high frequency horns, when used with the 713C High Frequency Receiver as the driving unit:

Code	Distribution Angle	Recommended Cross-over	Upper Limit of Frequency Response
KS-12024	30-40° vertical; 50° horizontal	800-1000	15,000
KS-12025	30-40° vertical; 80° horizontal	800-1000	15,000
KS-12027	90-100° vertical; 90° horizontal	800-1000	15,000

A 12-inch direct radiator, such as the 728B, is conveniently installed as the "woofer" unit in any divided-range system to complete the coverage down to the lowest frequency required. The 702A Dividing Network accomplishes the necessary division of energy into high and low frequencies, with a cross-over at 1000 cycles.

When the specialized characteristics of a woofer-and-tweeter monitor are not needed, the new direct radiator 755A, 756A and 728B units will furnish technical personnel with a distortion-free, realistic reproduction of the transmitter signal, as single-speaker monitors. Use of the single-speaker monitor is particularly advantageous for "executive" as distinguished from technical control monitoring, with installations in executive offices or operating spaces throughout a broadcast studio or transmitter building.

Recording studio monitoring, like broadcast station monitoring, requires the finest in loudspeaker performance. Frequency balance, distortion, and other characteristics of the signal *must* be carefully presented to the operating personnel by the monitoring system. The exactness of reproduction in the new Western Electric speakers is the basic answer to the fundamental requirement of technical monitoring.

Motion Picture Needs

The special needs of motion picture theatre sound systems are well understood in the industry. The primary requirements for speakers in movie theatres are:

(1) Speakers must have high power capacity with high efficiency, and provide a wide dynamic range.

(2) Distribution pattern must be controllable to match the size and shape of individual theatres.

(3) Close control of the frequency balance and other characteristics is necessary to insure the proper "presence" and to add effectiveness and drama to speech, music and every kind of sound effect.

The new Western Electric high-level systems have been designed to provide all of the characteristics needed in a theatre sound system. The range of power levels up to 120 watts covers the sound level requirements of every size of theatre from

(Continued on page 30)

1. "Music While You Ride" by Frank Nickel, *Western Electric Oscillator*, p. 22, March 1947.
2. "The 757A Loudspeaker", *Western Electric Oscillator*, p. 16, March 1947.

What Makes a Good Loudspeaker?

How faithfulness in reproduction is achieved in the design and manufacture of new loudspeakers

By R. S. Lanier

WHAT IS high quality in a loudspeaker? As an electro-acoustic transducer, a loudspeaker radiates an acoustic wave form equivalent to the electrical wave form reaching it from the other components of the system. As the final element in a system for entertaining or informing a listener, a fine loudspeaker, given faithful reproduction and transmission in the preceding components of the system, projects music and speech which are faithful reproductions and therefore satisfying to the listener.

A poor loudspeaker will destroy the quality of the finest system, although a fine speaker cannot project sound of higher quality than that of the electrical signal reaching it. A fine loudspeaker is thus an essential link in the chain of high quality reproduction.

These are simple statements of loudspeaker performance, but the achievement of such performance is a complex problem. An examination of the design objectives which guided the development of the new Western Electric loudspeakers, and the methods used to incorporate them in the speakers, will serve to illustrate the general principles of loudspeaker design, and will give a clearer understanding of the advanced reproduction qualities of these new speakers. The most commonly accepted criteria for high quality loudspeaker development can be grouped under the following general headings:

1. A wide frequency range must be reproduced;
2. Uniformity of response over the range reproduced is extremely desirable;
3. All forms of distortion must be reduced to very low levels;
4. A high degree of damping is desirable for faithful reproduction of transients and to improve the linearity of the system;
5. Uniform distribution of energy over an appropriate angle is required;
6. The power capacity must be adequate to cover the peak powers expected.

Satisfying the Ear

The qualities listed above are all necessary for fine loudspeaker performance. Their application in a loudspeaker design is a difficult problem, because the human ear is a most particular and sensitive instrument, giving importance to many effects the engineer might overlook and often finds difficult to measure. Thus the designer of a fine loudspeaker must have full command of the electro-mechanical engineering art, and in addition, he needs a wide background of listening experience in order to interpret the actual subjective effect of various characteristics on the listener. The pioneering history of Bell Telephone Laboratories in electro-acoustics and its pre-eminent position as a development agency in this field have built up the kind of experience that is essential in this very difficult art.

Consider first the question of frequency response, undoubtedly the most discussed characteristic of loudspeaker design. No subject has been more beclouded and misunderstood than the relative merits of various loudspeakers as expressed by frequency response curves. Although a number of methods of measuring the frequency response of a loudspeaker are well understood in the industry, different methods are used by different manufacturers. In addition, it requires long experience to correlate curves taken under laboratory conditions with the subjective effect of the loudspeaker in a normal listening application. Thus the sound technician—and even more the layman—should not attempt to interpret the performance of a loudspeaker solely from curves published to show its frequency response. Even when published with the best of intentions, such curves are likely to be misleading as to what the ear is actually going to hear when the loudspeaker is installed in a living room or other enclosed space. But, though frequency response curves do not tell a simple story considered alone, they are extremely valuable as aids to the experienced designer.

Response Curves as Design Tools

In the design of the new Western Electric speakers, many carefully derived frequency response curves have been used as engineering tools to guide the development engineer, and typical of such curves are those shown in Figures 1, 2 and 3 on pages 34 and 35. In Figure 1, the response of the 728B is shown under "dead room" conditions, at a point on the axis and at two points 15 degrees and 30 degrees off the axis.

Figure 2 shows the response of the 728B in a "listening room". This is a carpeted room simulating the characteristics of a living room. The measurement was made at a point on the speaker axis. Reflection effects due to the surfaces of the room are clearly seen. The "averaging" of the energy is demonstrated by the downward trend of this curve as compared to the upward trend of the "dead" room curve.

The "raggedness" of the listening room response, due to room reflections, obviously exists at a particular point in space for steady-state conditions (a continuing tone). Speech and music, however, are composed chiefly of transient impulses, and many of the standing waves do not have time to occur. Furthermore a listener, because of his binaural hearing, tends to average the pressure existing at two points, thus further minimizing the effect of reflections. It is interesting to note, in this connection, that from 80 to 95% of the sound heard under average listening conditions is reflected sound, even if the listener is sitting near the axis of the loudspeaker—indicating the vital importance of the room characteristics in determining the "sound" of a loudspeaker.

Figure 3 is the "dead room" response of the 755A speaker, at a point on the axis.

The over-all frequency response of the new Western Electric speakers has been designed, with the actual effect on the ear as the final criterion, to combine all such factors into a smooth, wide range response that would produce complete clarity and realism. The success of the design has had in some cases a curious effect. Some listeners, used to the overbright, rather "harsh" quality of loudspeaker systems with a "peaky" high frequency characteristic, and to the rather high noise level common in such systems, feel on first hearing them that the new speakers are lacking in high frequency response. But they soon discover, with further listening, that the new speakers actually have a wider, smoother high frequency range, that produces high clarity and definition without the harshness of the "peaky" speaker; and that the reduction in extraneous noise—such as surface noise—is a real gain, not achieved at the expense of high frequency response.

The same use of careful measurement together with reports from many experienced observers as to the subjective effects, was used to guide the engineer in producing a design with a very low level of all forms of distortion. The reduction of distortion to negligible levels in a direct radiator speaker is difficult, but it is important if the sound produced by the speaker is to give pleasure to the listener. The listener "acceptance" of the new speakers, the fact that the listener feels pleasantly relaxed when listening to them, is to a great extent a measure of the extremely low distortion level achieved in the design.

Factors in Low Distortion

Many factors contribute to this low distortion level. Some of the principal ones are:

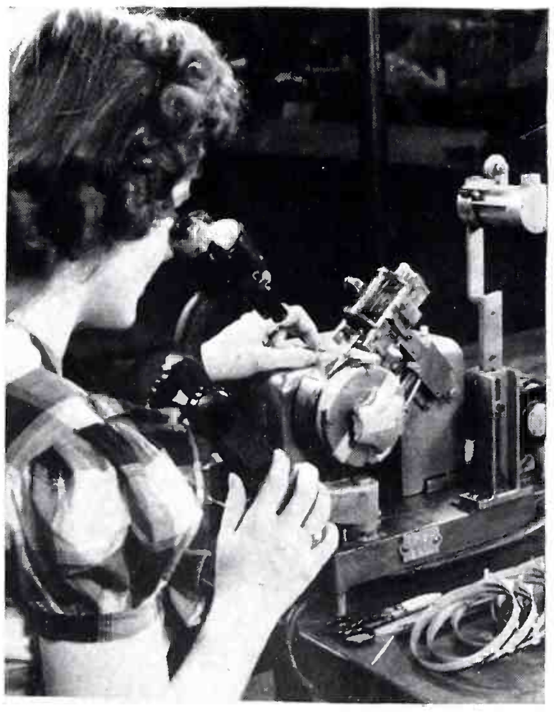
1. The voice coil has been made large for excitation of the whole cone in a uniform manner;

2. The special "shallow cone" design minimizes the interference effects which normally occur at high frequencies in cones of steep section;

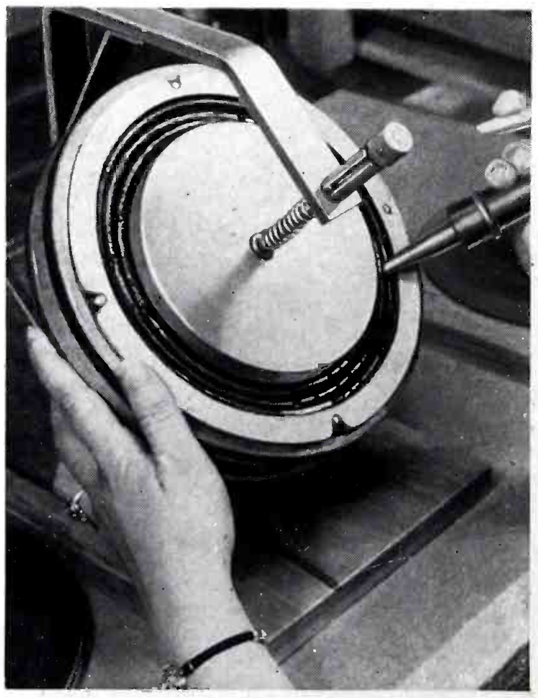
3. Edge damping, a feature of the new designs, reduces distortion caused by cone breakup by attenuating reflections from the edge. It improves the linearity of the mechanical system in general by providing damping in the bass where the air loading is low, reducing the bass resonance and producing a smoother response;

4. The shape and construction of the cone have been carefully selected for most desirable vibrational characteristics.

The mechanical characteristics of the new direct radiator speakers were considered with the same care as the electrical, in order to be sure that the speakers would be fully applicable to use in all forms of sound reproduction systems. Thus the new "flat" cone design was attractive not only for its acoustic superiorities, but because it could be combined with a new magnet configuration to produce the unusually small front-to-back dimension of the new speakers. The magnetic gap has been made somewhat wider than earlier standard practice would dictate, for increased stability and uniformity of characteristics over long


Winding machine produces voice coils of uniformity with each turn anchored permanently in position.


Unusually large magnet of Alnico is used in new 728B speakers to assure efficiency and quality.


Revolving fixture and special application device are used in applying cement to edge suspension.

periods of time under the most severe conditions of use. For improved efficiency a very large magnet of Alnico—weighing ten pounds in the 728B—has been incorporated in the new speakers.

Dual Systems

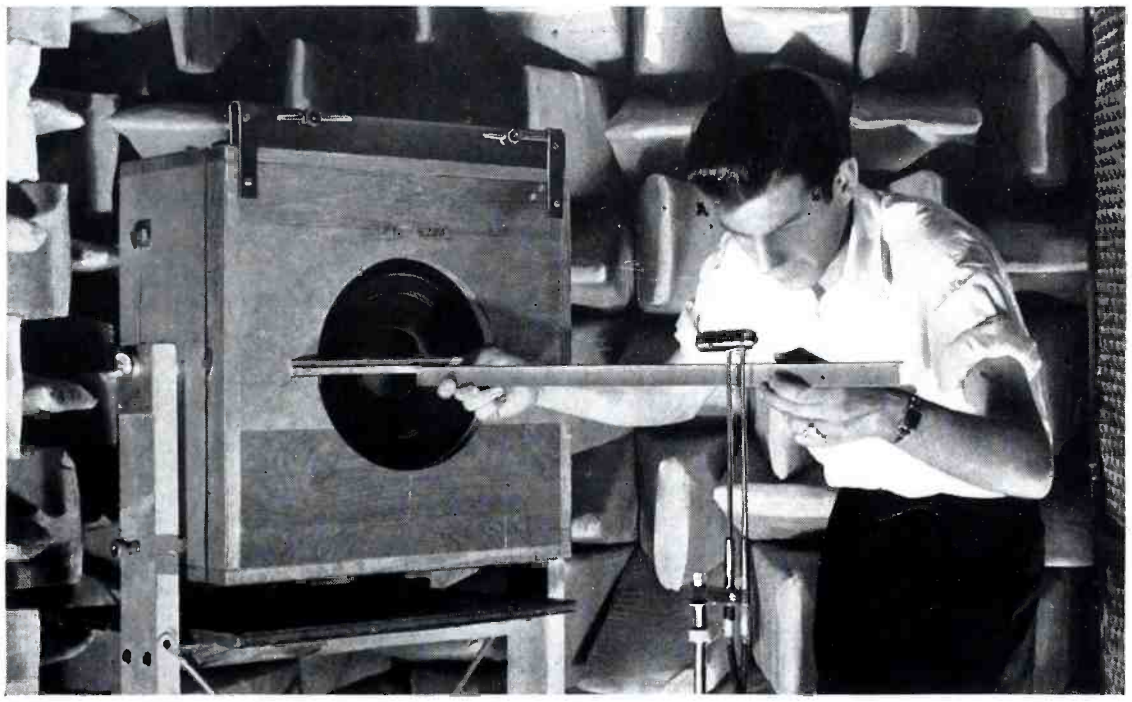
The same general considerations with respect to frequency response, distortion, etc., guided the design of the new Western Electric high frequency receivers and horns, and of the dual systems in which they play a part. The new high frequency receivers, the 713B, with a phenolic diaphragm, and the 713C, using an aluminum diaphragm, are driven by an edge-wound voice coil, which maintains efficiency in the high frequency spectrum covered by these receivers. The new sectoral exponential horns, the KS-12024, KS-12025, and KS-12027 used with the high frequency receivers, are of cast aluminum. These horns have constants so chosen that a smooth frequency response is maintained over the whole range covered by the high frequency units.

In the design of the dual channel systems, special attention has been given to the choice of cross-over frequency, to the balancing of energy in the two channels, and to the relative positions, in the vertical and horizontal planes, of the low and high frequency speakers. A cross-over point of 800 to 1000 cycles has been chosen as indicated by careful listening tests as to the most effective design.

In the high-level systems, exponential horns for both low and high frequency projection, together with driving units of special high efficiency design, provide the increased efficiency which is economical in reproducing systems operating at high power levels. The low frequency drivers, the 12-inch 754A and 754B, have voice coils of edge-wound copper tape, and special magnet materials to furnish increased efficiency. The 754B has a phenolic dia-

(Continued on page 34)

Automatically recorded graph showing frequency response of a completed loudspeaker comes off the machine specially designed by Western Electric to make this final quality test of the manufacturing process.



Setting up a 728B speaker in the dead room for the frequency response test includes accurate placement of the 640AA Microphone, which picks up the energy for measurement by the automatic recording device.

Magnetizing the speakers with a controlled pulse of energy produced in condenser discharge device.

Loudspeakers lined up for the sweep-frequency noise and rattle test, carried out by the operator in left foreground. The automatic recorder for the final frequency response test is in the middle background.

WLAW–A New Top-Power Voice from New England

By George de Mare

"THIS is WLAW—the Voice of Industrial New England!" That's the way the new 50 kw Hildreth and Rogers station of Lawrence, Mass., now proudly announces itself. For WLAW, "680 on your dial" a station whose heritage lies deep in the life of its region, has become one of the three 50 kw's in New England—its only rivals in power being WBZ, Boston and WTIC, Hartford.

WLAW, on the air an hour longer per day than any other New England station, is also fortunate in its lower frequency position on the dial which gives it greater coverage. More than 25 papers from the *Quincy Patriot-Ledger* in Quincy, Mass., to the *Daily Monitor* and *New Hampshire Patriot* at Concord, N. H., list WLAW's programs, and at the inauguration of its 50 kw power status two months ago, letters flooded in from about every city and town in Massachusetts and from as far south as Auburn, New York, and as far north as Canada's Montreal, in Quebec Province; Halifax, Nova Scotia; Cornwallis, Nova Scotia and St. John, New Brunswick. One Royal Canadian Mountie wrote in from Nova Scotia that the signal came in as clear as a bell and he looked forward to many pleasant hours listening to this big voice from America.

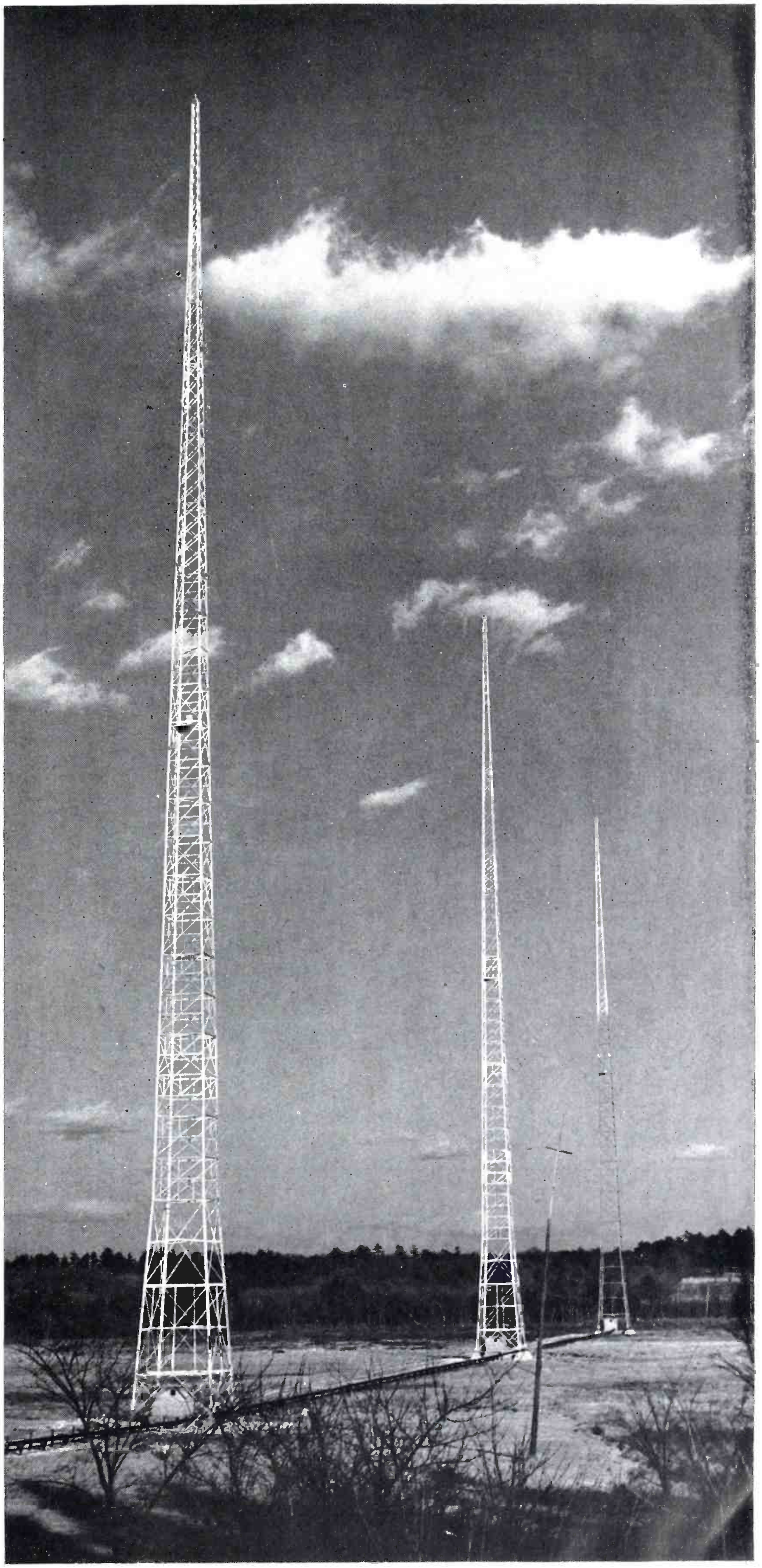
We went up to Lawrence, Mass., to look over WLAW's new $350,000 plant and find out more about its policies, aims and background. It is an ABC basic station—that is, it airs all of its network's programs in its region. But it is more than that. It is also a true regional station, owned by three generations of an old New England family, operated by New Englanders and with its roots deep in New England soil.

WLAW's general manager, Harold B. Morrill, a cautious, hard-headed, deeply respected man with a rich sense of the duty of a station to its community, told us the story:

Owned by Newspaper Publishers

"Our station was started back in December 1937 as a 1000-watter by a newspaper publisher, the late Alexander H. Rogers, and is owned by a family in the newspaper publishing business. In 1940, the station jumped to 5000 watts. Irving E. Rogers, the founder's son and owner of the Lawrence *Daily Eagle* and *Evening Tribune* became, on the death of his father, president in 1942. As you know, men who run newspapers like the *Eagle* and *Tribune* are community conscious. They have to be. They also have a closer relation to their region than might be otherwise possible. So our station is rooted in this tradition of service to the community and the region. Regional news is important to us and in fact anything that happens in New England rates our major efforts. Typical of this was our exclusive on-the-scene broadcast, coast-to-coast, of the sinking of the U. S. Submarine *Squalus* some years ago off the shore of Portsmouth, N. H. As for community service? Well, when the station helps raise $1,200,000 for a hospital in the city, as it is doing right now, that is routine. We were the opening gun in the "Safety on the Highway" campaign for the International Association of Chiefs of Police, but that too is important to the region, as it is to every region. When we air our "School and Home Program" giving the Superintendent of Schools and important local educators a chance to discuss community public school problems, we feel that's basic to our station's policies, something we can't do without. . . . And when we join forces with four community newspapers to help raise a fund to establish and maintain a summer camp in Essex County for 400 children crippled by infantile paralysis, that too we regard as exemplifying part of the basic job of this station. . . . Mr. Irving Rogers feels as I do that our major job here is in the nature of public service—doing everything possible to develop and further the interests of this area.

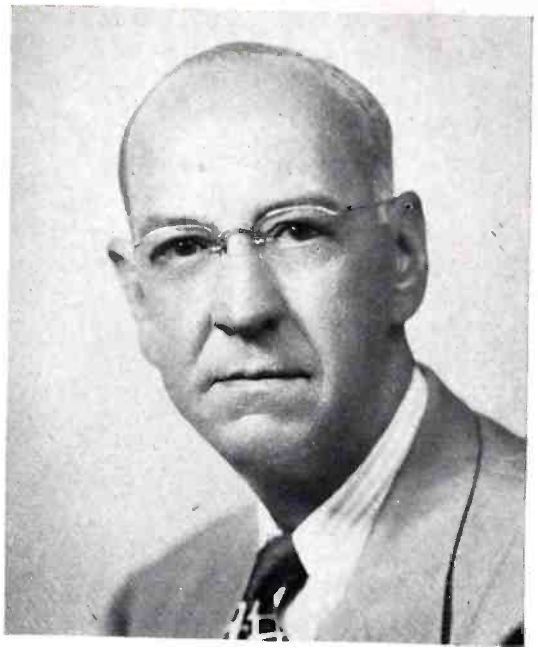
"But of course if a station is going to have listeners and do a good community



WLAW's 440-foot quarterwave antenna tower array beams the station's programs north toward Canada and south toward the southern tip of New England.

IRVING E. ROGERS
President

ALEXANDER H. ROGERS
Founder of WLAW



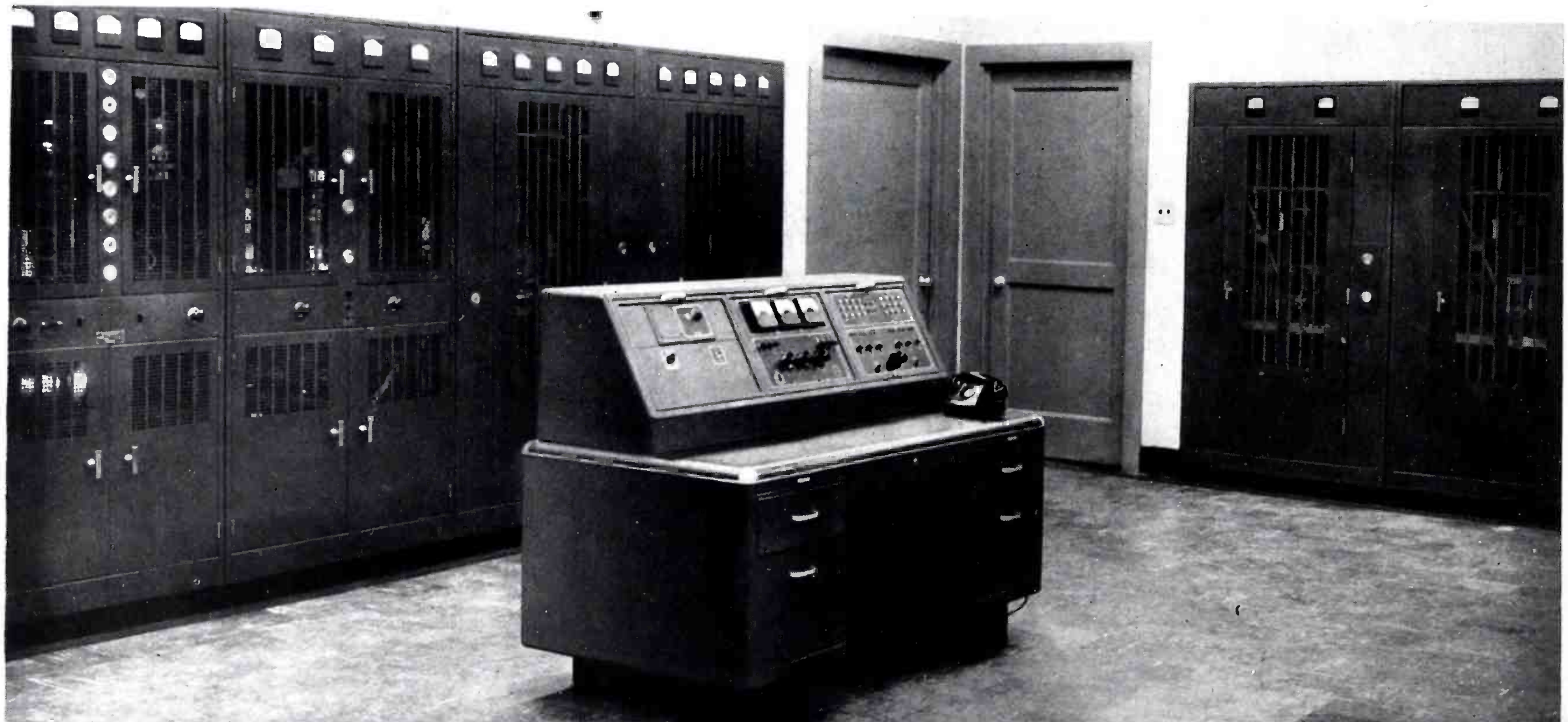
HAROLD B. MORRILL
General Manager

job, it must also have good entertainment. . . . We're lucky, naturally, in being a basic station. . . . We get the American Broadcasting Company's best shows—the Bing Crosby and Henry Morgan shows; Theatre Guild on the Air; the Lone Ranger; Sammy Kaye, Professor Quiz, Don McNeill and his Breakfast Club; Tom Breneman's Breakfast in Hollywood; Johnny Olsen and his "Ladies Be Seated"; top commentators like Walter Winchell, Elmer Davis, Baukage, Drew Pearson, Louella Parsons and Jimmy Fidler; and the Boston and Detroit Symphony Orchestras, and other national favorites. But with it, we have a few of our own, and they tie into the community too. . . .

Home-Grown Programs

"One of the shows of which we're proud has uncovered a lot of talent from this region. . . . This is the *Stargazers*—a variety show. . . . It's not an "amateur hour" but a revue made up of young people on their way up. . . . WLAW uses this program to 'discover' them. . . . Most of the young people on the show come from the communities and factories around here. Their talents are home-grown. . . . On the Stargazers at present are the Poulin Sisters—a quintet of talented vocalists, the Vocalettes, girls' chorus with soloists and musicians, Bill Keenan, baritone, Ann Coyle, Marjory Largay, Teresa O'Mara and Virginia Bunker, soprano; Robert Garneau, young concert pianist; the Melody Men, quartet, and others to whom "Stargazers" may be the gateway to careers in radio, stage and screen.

Another opportunity for talent in our area is the "Opportunity Hour." Since its inception in 1937, this program has given more than 3,500 people a chance to display their talent and made the station known throughout our region as 'the Sta-



WLAW's new 50 kw Western Electric transmitter with the Transmitter Control Desk and at right rear a 5 kw auxiliary transmitter. This equipment is in central area of handsome new transmitter building shown on page 14 and is a part of WLAW's $350,000 plant situated in Burlington, Mass., eight miles from Boston.

GEORGE A. HINCKLEY
Chief Engineer

MATTHEW J. NOONAN
National Sales Manager

FRED A. SULLIVAN
Director of Public Relations

tion of Opportunity'. . . . We have a lot of other programs we are proud of too—programs that have built up large followings. . . . *The Westernaires,* Guy Borrelli, concert pianist and composer, *Pickabit,* the *Yawn Patrol,* Jack Stevens commentary from Boston, exclusive weekly boxing bouts from Boston's Mechanics Hall and the Arena, and a dozen others. . . . Perhaps the station's program day for a typical Thursday from sign-on to sign-off showing only programs originated by the station would give you the best idea of what sort of fare we offer our region. . . . The times not indicated are devoted to network shows:

A Typical Program Day

6:00....RFD 680 with Ray Bradley
6:30....Yawn Patrol
7:30....Lowell News
7:45....Yawn Patrol
8:00....WLAW News
8:15....Among Us Girls
8:30....News
8:35....Morning Devotions
8:45....Shopping with Polly
10:00....My True Story
10:45....The Listening Post
12:30....Jack Stevens
12:45....The Music Box
1:30....News for the Blind
2:00... Kiernan's News Corner
2:15....Ethel & Albert
2:30....Bride & Groom
3:30....Hit Tunes—Bing Crosby
3:45....Hit Tunes—Part 2
4:00....The Westernaires
4:30....Hit Tunes—Part 3
4:40....Regional News
6:00....WLAW News
6:05....Employer Service
6:15....Jack Stevens
6:30....Twilight Time
6:45....Guy Borrelli
7:00....Headline Edition
7:15....The School and Home Program
8:15....The Christian Science Monitor Views the News
9:30....The Stargazers
10:00....New England's Tops
10:30....Fantasy in Melody
11:00....WLAW News
11:15....Joe Hasel-Sports
11:30....Gems for Thought
11:35....Dance Band
12:00....The Bob Moore Show
1:00....WLAW News
2:05....Sign Off

Later we asked President Irving Rogers to tell us something about the community and its people.

"This region is, of course, New England to the core with all that name implies," he said,—"fine homes and green rolling hills. . . . Boston with its winding streets . . . the industrial sections up here around Lawrence . . . the quiet towns branching out. There are no great open spaces here anymore. The trains stop every ten minutes at some suburban towns. . . . The statues in the town squares—well you've seen them. . . . It's cold here in the winter. . .

Survived Flood and Hurricane

We've survived—that is, our station has survived in its crowded ten years—one major flood and one major hurricane. . . . We stayed on the air 41 consecutive hours and helped the way everyone else helped—doing jobs for the Red Cross, public safety and highway services, hospitals and the general public at large. A station shows up well in an emergency. This New England community we're trying to serve has more than 4,000,000 people within sound of our voice and about 1,098,000 families with radio sets. . . . It's effective purchasing power income is more than $4,600,000,-

(Continued on page 36)

JAMES T. MAHONEY
Program Director

DAVID M. KIMEL
Local Sales Manager

GEARING TIME TO SCIENCE

A New Frequency Standard Crowns Man's Efforts to Measure Time More Accurately

By A. W. Colledge
Radio Division, Western Electric

A frequency of 100 kc, accurate to *one part in 10^8 per day*. Such is the performance capability of the Western Electric D-175730 Primary Frequency Standard, the most recent of a long list of Bell Telephone Laboratories developments in the field of precision frequency and time instruments.

Accurate to one part in 100 million! Use this electrical frequency source and frequency dividers to drive a clock. Hold its rate constant by compensating for the aging effect of the crystal, and you have time to an accuracy of one second in three years!

Is this a scientific toy to be locked in an air-conditioned, shock and vibration-proof vault? Far from it. It is a rugged, portable instrument which has performed faithfully in the far flung theatres of war, under wartime conditions.

From the Dawn of Civilization

Before further describing this remarkable instrument, it may be of interest to go back to the very beginnings of civilization and see how Man has progressed in his methods of time measurement, and how in the latest stages Electronics has taken over this vital task. Length, mass and time are the fundamental units of science. The units of length and mass are man-made blocks of ageless platinum-iridium. They can be seen, felt and duplicated. The unit of time, however, is far more elusive, and its measurement is associated with the movement of the fixed stars, as they traverse the field of an astronomical telescope.

The measurement of time goes back to the beginning of time itself. To early man, it was the span from dawn to dark of a day. As he developed the power of observation, he roughly divided the day by the position of the sun as it crossed the heavens, and by the shadows on the earth which moved with it. Longer spans of time became associated with the cyclical phases of the moon, and with the changes of the seasons.

Our present calendar stems from the Chaldeans, an ancient semitic tribe of sun worshipers which inhabited the lowlands of the Tigris and Euphrates rivers. In honor of the Sun, the Moon and the five planets which were their Gods, came the Anglo-Saxon names of the seven days of the week which still carry the names of the planets and the Ancient Gods: *Sun* day, *Moon* day, *Tyr* day, *Woden* day, *Thor* day, *Frigga* day, and *Saturn* day.

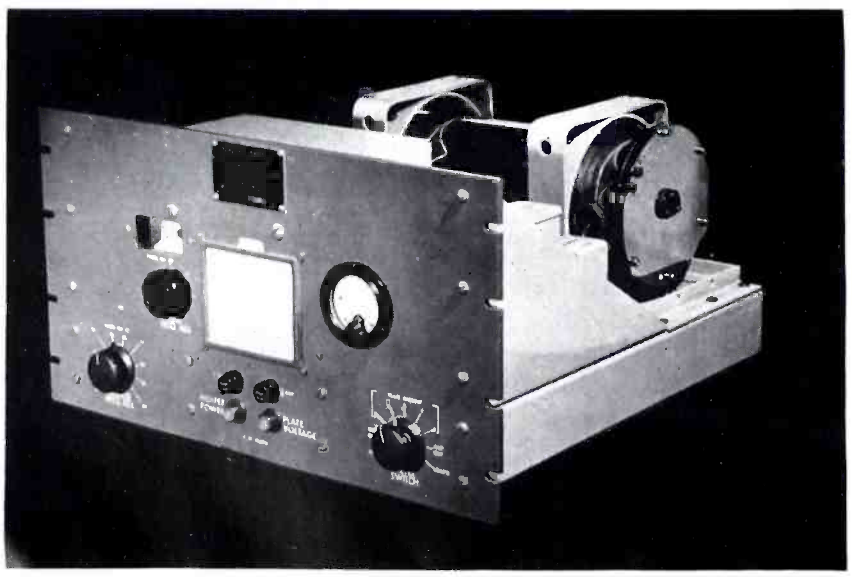
This Babylonian tribe attributed mystical powers to the number twelve, its multiples and subdivisions, for they knew there were 12 full moons a year, and 12 constellations in the ecliptic belt of the Zodiac. The year they divided into 12 months, the day into two blocks of 12 hours each, the hour into 60 minutes, and the minute into 60 seconds. From them also came the division of the circle into 360 (12 x 30) degrees.

The sundial is the oldest time-measuring device, and is credited to this same tribe as far back as 2,000 B. C. Its use spread to India, China, Egypt, Greece, and to Rome in 400 B. C. With the Roman conquests, it spread to all Europe.

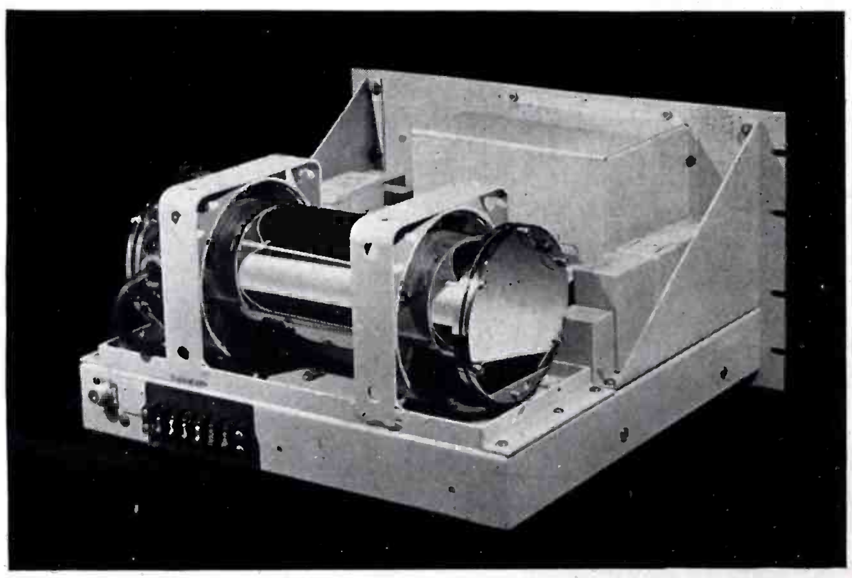
The first mechanical means of measuring time was the clepsydra, a water clock. In its simplest form, it was merely a container into which water flowed. The height of the water, as read directly, or by a float, measured the passage of time. In India, a brass hemispherical bowl with a small hole in the bottom was floated on water. The bowl would fill and finally sink, at which time an attendant would ring a gong, and empty the bowl. This, at least, showed the passage of time, and was fairly satisfactory —if the attendant was.

As the centuries passed, the water clock became quite complicated. A hand moved over a dial to indicate the time, the hours were struck, lions roared, cocks crowed, drums were beaten and motions were executed by small figures. To do all this required an elaborate mechanism of gears and levers.

In countries where no flow of water was available, a weight was substituted as the driving power. This required the use of an attendant to wind up the weight, an hourly job. With no control except friction over the falling weight, these clocks were not as accurate as the water clocks, which varied about two hours a day. It was not until 1360, when Henry De Vick added the crown wheel, escapement and balance, that clocks became useful as well as entertaining. To the already complicated



Front view of the new Western Electric 100 kc D-175730 Primary Frequency Standard. It is accurate to one part in 10^8 per day or one part in 100 million!



Rear view of Frequency Standard. When its rate is held constant by compensating for aging, it can hold time to an accuracy of one second in three years.

pageantry of the water clock were added dials showing the motion of the sun, moon and the planets, and a calendar with all the church festivals. But only one hand was used to show time!

Invention of the Pendulum

History does not record the sermon which Galileo ignored as he sat in church observing the rhythmic swing of the light chandelier. It does record, however, that these observations, which he made in 1583, led to the invention of the pendulum. When, in 1657, Huygens added a pendulum to a clock, measurement of time to minutes and seconds finally became possible—3,600 years after these units had been defined.

Into the manufacture of more accurate clocks went amazing skill and mechanical ingenuity, and the modern astronomical clock, with its driving and slave mechanism, is truly a mechanical marvel. Kept with tender care in a vibration-free vault, under constant temperature, it will keep time to an accuracy of 1 part in 8 million —one one-hundredths of a second a day —a long stride from the two hour-a-day accuracy of 300 years ago.

This is excellent accuracy, but today's needs call both for greater accuracy, and an electrical impulse of very high frequency. For example, to plot the position of a ship at sea by the time difference of signals received from two shore stations requires a precision high frequency source. The same precision is required for checking the present-day radio and radar signal frequencies of hundreds of megacycles.

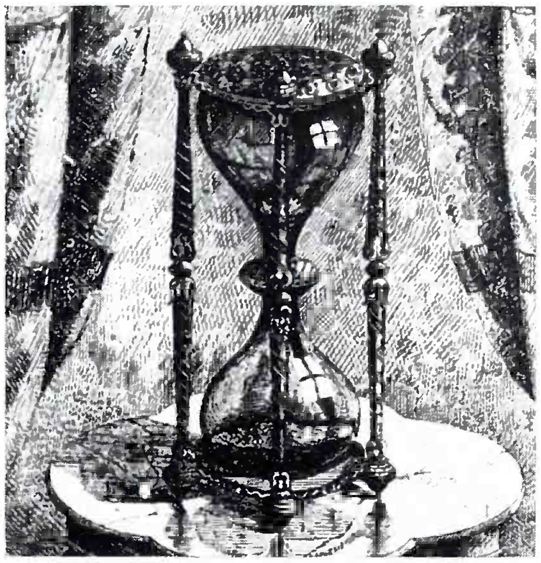
An electrical signal can be generated by a clock, but its frequency would be too low. The time of the swing of a pendulum is a function of its length. Practically all precision clocks have one-second pendulums, and physical factors limit decreasing this time beyond 1/5 of a second. Electrically driven tuning forks can develop a frequency in the order of several hundred cycles, and if the temperature of the fork be kept constant, reasonably good accuracy can be obtained. Again, physical factors impose a low limit on the maximum frequency which can be generated.

To solve this problem, the scientists of Bell Laboratories turned to the piezo-electric properties of quartz crystals. Exhaustive studies finally led to the "GT" cut crystal as the most stable crystal element, with relative freedom from temperature effects. This type of crystal, a highly stabilized bridge oscillator circuit and an electrically controlled heater which holds the crystal temperature constant to .01 degree, became the Western Electric D-175730 Primary Frequency Standard.

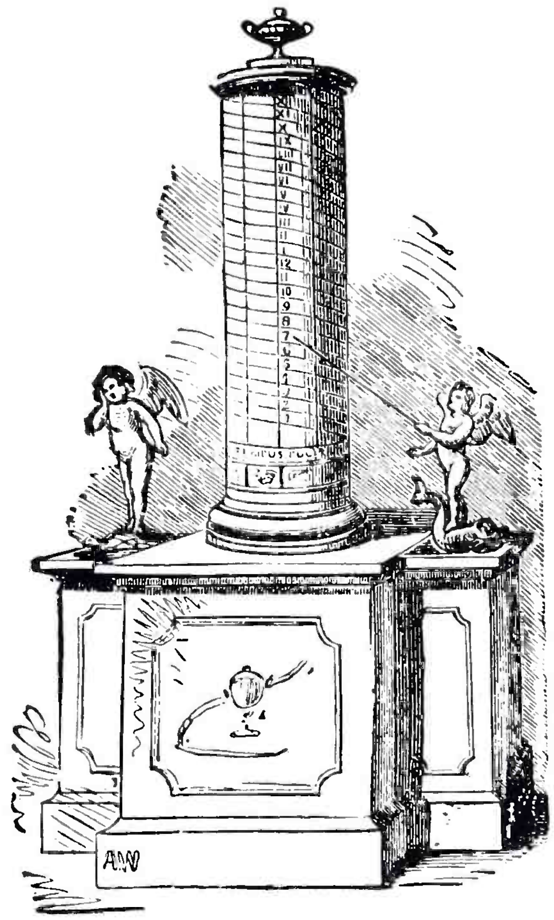
"Super Thermos Bottle"

The crystal is suspended by a series of wires inside an evacuated glass envelope. This envelope is inserted into a copper cylinder, upon which is wound the temperature-sensitive bridge of the electronically-controlled heater. To minimize heat loss this assembly is mounted inside a glass thermos flask, with a thermo plug on each end. The flask is encased in a second copper cylinder which is closed and upon which are wound the coarse heater coils. Surrounding these coils is a layer of heat insulation and a plated outer housing. The entire assembly is cradled in rubber pads for shock and vibration protection. The shock-insulated oven assembly is mounted on a chassis 19 inches deep on which the electronic equipment is assembled. The chassis is attached to a panel 19 inches wide and 10½ inches high, on the face of which appear the various controls. The entire unit weighs but 90 pounds and is suitable for standard relay rack mounting. It requires current supplies capable of furnishing 115 volts a-c, 6.3 volts a-c and regulated 135 volts d-c.

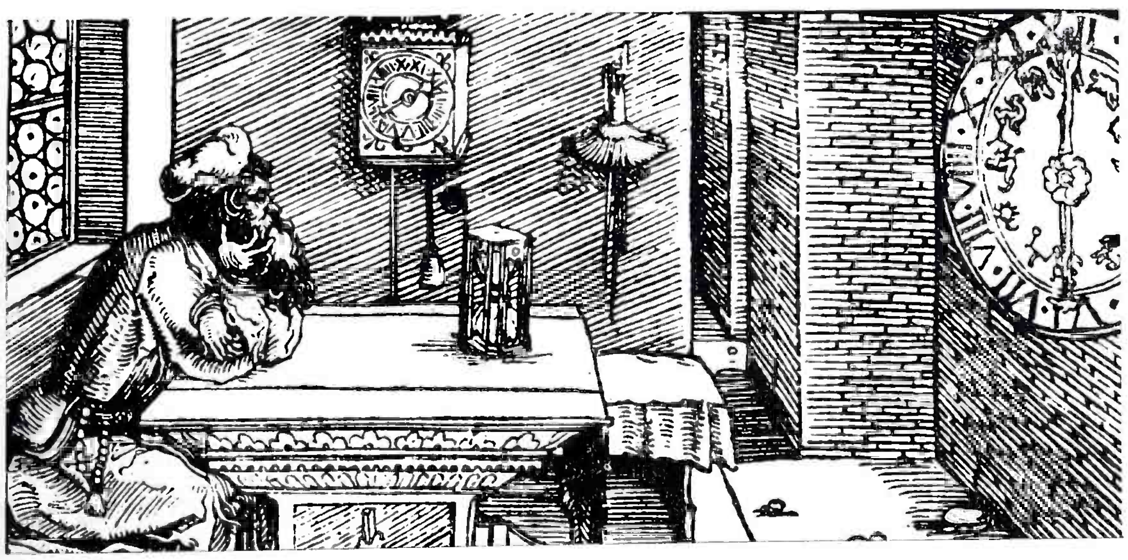
(Continued on page 36)



Medieval hourglass, widely used for measuring time before invention of the pendulum by Galileo.



The clepsydra measured time with a controlled flow of water, which drove mechanisms of great variety



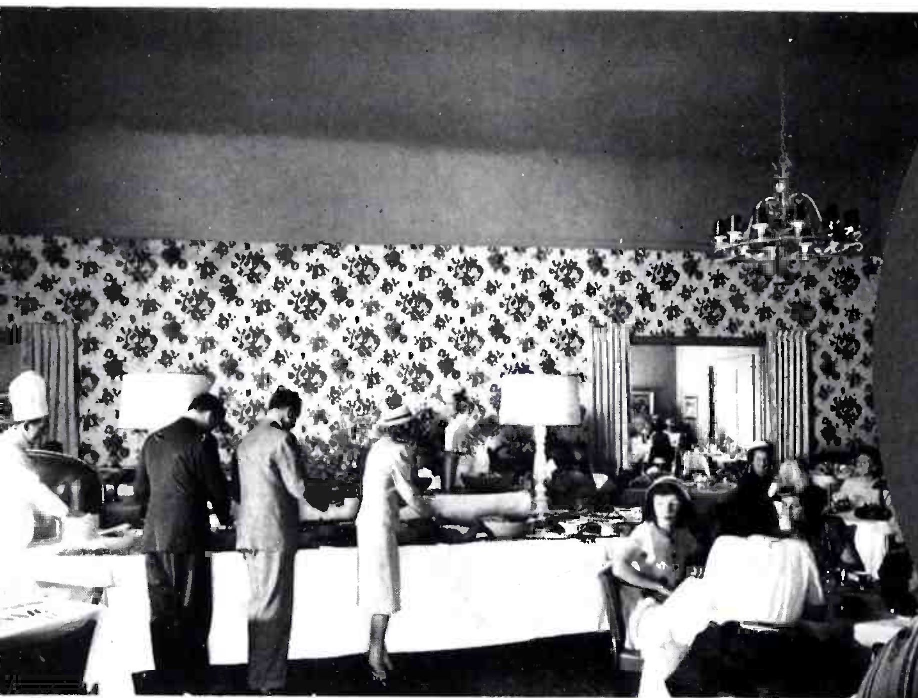
A 16th century woodcut, "On the Nature of Time," shows a philosopher contemplating various sorts of time-measuring devices used at that period, including an hourglass and two early weight-driven clocks.

The oldest time-measuring device, the sundial, goes back 4,000 years to the ancient Babylonians

In the Scottish Rite Auditorium at San Francisco, Western Electric 728B Loudspeakers are serving the public. Speakers may be seen right and left of auditorium stage.

FOR THE NEW ERA IN SOUND

From concert auditorium to moving train, from cocktail lounge to city hall, Western Electric's modern line of loudspeakers spread new quality sound.

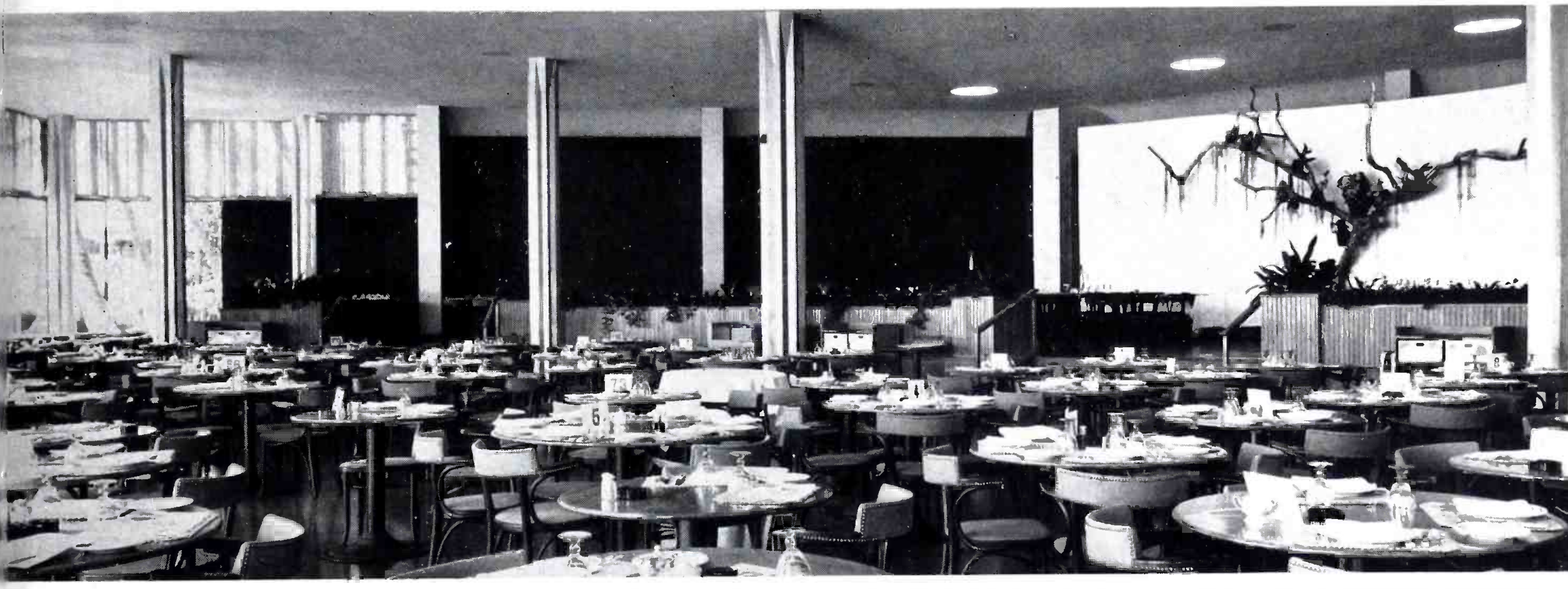


In the buffet of the noted Chukker Club at San Mateo, Calif., guests have music with new beauty of tone through these speakers.

San Francisco's City Hall — one of the handsomest buildings of its kind — uses Western Electric loudspeakers. Placed in the rotunda, they give superior speech or music reproduction for public ceremonies. In public buildings of this type a new order of sound quality is being achieved with these advanced loudspeaker designs.

Left: Music from the new speakers will fill drawing rooms of trains like the modern Zephyrs of Chicago, Burlington & Quincy, Western Pacific and Denver & Rio Grande Western.

Above: Typical of buildings requiring good quality speech and music is the Civic Auditorium Building in San Francisco which uses multiple 728B speakers.



Music on Waikiki Beach in exotic Hawaii. Here in the main dining room of the magnificent Royal Hawaiian, one of the world's famous hotels, guests may hear "sourceless" dinner music, distributed through these new high-quality loudspeakers. Unobtrusive circular grilled openings in the ceiling indicate position of the loudspeakers.

Listening to a symphony on a fine radio-phonograph such as this Capehart is an enjoyable event. The 728B speaker helps give this superb fidelity.

Another use of these loudspeakers is in finer reproduction of the services in great churches such as St. Albans Cathedral in Washington, D. C. Loudspeakers give a new quality realism and "presence".

A NEW LINE OF AMPLIFIERS

. . . designed to fit like building blocks into any installation—large, medium or small

By H. W. Augustadt
Bell Telephone Laboratories

FLEXIBILITY is the keynote of a new series of "building block" amplifiers just announced by the Western Electric Company. The designation "building block" amplifiers is accurately descriptive of the simplicity with which a system employing these units can be modified or expanded to provide additional facilities. This new series is an integrated group of three amplifiers, namely, a booster or preamplifier designated 141A, a 25-watt power amplifier designated 142A and a 75-watt power amplifier designated 143A. These units are specially designed for program distribution systems and provide the utmost in flexibility in use, quality in performance and reliability over years of trouble-free service.

In addition, the Western Electric Company has announced an ac-dc amplifier, designated 140A, primarily intended for wired program and general purpose monitoring service. This 140A Amplifier satisfies every wired program service application from the smallest cocktail lounge to large restaurant installations, not only in a-c but also in d-c power districts.

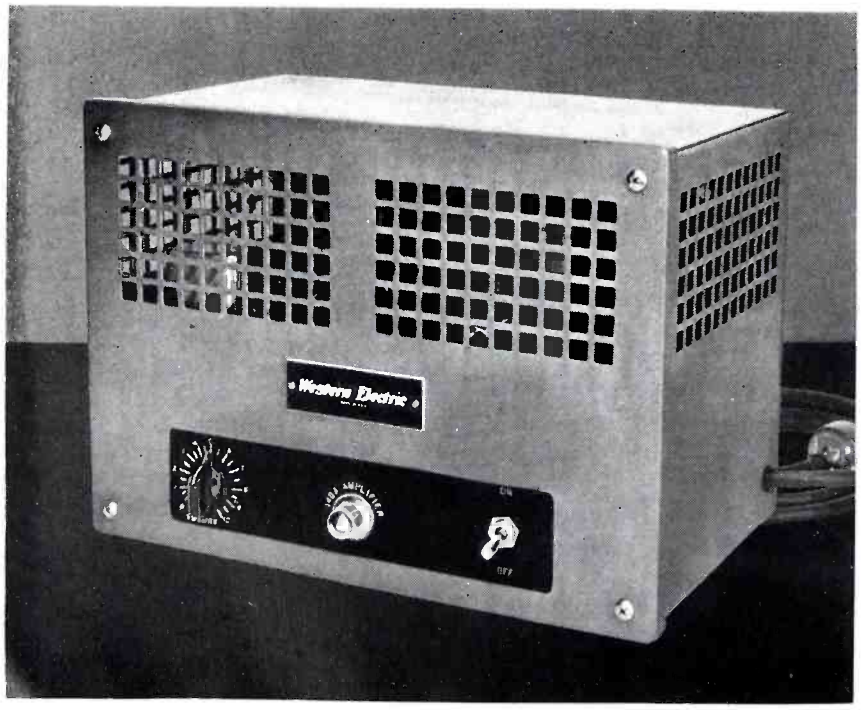
Designed by Bell Telephone Laboratories and manufactured by the Western Electric Company, these amplifiers have behind them more than 30 years of experience in engineering and producing equipment for sound distribution systems. Application of this wide experience in the design of these new units has produced equipment satisfying every requirement of the sound distributing field. These amplifiers are going in production and will be available in the latter part of this year. The "building block" series of amplifiers will be discussed first, followed by a description of the 140A Amplifier.

Flexibility of Design

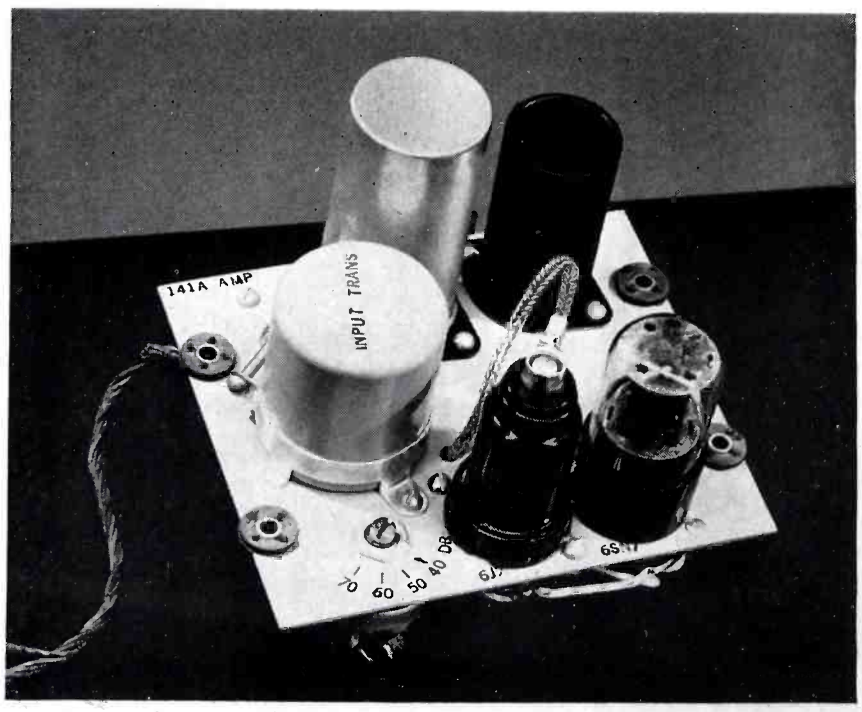
The design objective set for the integrated series of amplifiers was that they should fit like "building blocks" into systems of any size from the simplest single-channel setup to the most complex multiple channel system, so that a simple system could be subsequently increased to any size or complexity by simple and economical addition of units. This objective was realized by designing one basic low-level amplifier for either preamplifier or booster amplifier purposes, and two basic power amplifiers, of 25-watt and 75-watt capacity. Flexibility of design is achieved by constructing the power amplifiers with space for mounting plates on which a wide variety of input facilities can be mounted.

The 141A Amplifier is a three-stage low-level amplifier operating from microphone or other low-level sources, to raise the signal to about line level. It is constructed with an adjustable gain control and has sufficient output capacity to serve as a booster or line amplifier. Thus all requirements for boosters or preamplifiers are satisfied with this one unit. As a booster, a single 141 can drive as many as 20 power amplifiers simultaneously, providing up to 1500 watts of power. The 141A Amplifier seldom functions alone; hence in order to make it as compact as possible, it was constructed so that it would operate from external filament and "B" supply sources.

The power amplifiers are similar in their system aspects; hence the description of the 142A 25-watt power amplifier will suffice to illustrate the application of both of these units. An exactly similar system setup may be constructed with the 143A 75-watt power amplifier if the additional power capacity is desired. Each of the power amplifiers is constructed as a basic chassis with two high impedance input channels. These channels are mixed in a master gain control. As previously stated, the power amplifier provides space for mounting plates on which a wide variety of input arrangements may be placed. It is also arranged to provide the filament and "B" supply requirements of one 141A Preamplifier.



The 1140A ac-dc Amplifier, coded 140A without the cabinet, for wired program and monitoring service, has complete freedom from grounding complications.



The 141A Amplifier shown above is a three-stage booster or preamplifier, designed to mount in the space provided on the 142A and 143A power amplifiers.

An idea of the versatility of the power amplifier design may be gained by considering the wide variety of input facilities this unit can accommodate. In one arrangement, a 141A Preamplifier may be mounted on it to provide adequate gain to raise the lowest level program sources to full amplifier output. In addition, since the amplifier has a two-channel input, it can simultaneously accept program material from a source of about line level. This assembly of 141 and 142 type amplifiers is designated the 142B Amplifier. Operation from program or telephone lines may be had by mounting plates carrying input transformers, instead of the above mentioned preamplifiers. The assembly of 142 Amplifier and an input coil designed for operation from telephone lines is designated the 142C Amplifier. Amplifiers in the 75 watt 143 series with similar input facilities bear similar designations. Likewise, combinations of a line channel with input transformer and a 141A Preamplifier channel can be employed (142D).

Versatility of Power Amplifier

In simple sound system setups, the 141A Preamplifier is mounted on either the 142A or 143A Power Amplifier chassis (codes 142B and 143B respectively) to form an a-c operated amplifier capable of raising low level sources to full amplifier capacity. This arrangement lends itself particularly to portable and rental type public address requirements. It can be universally used for installations requiring a single-channel paging and program distribution amplifier system.

The output circuit of the power amplifiers also has several noteworthy features. The load impedance is not critical and load impedances over the range of 2 to 24 ohms may be accommodated without reduction in rated power output or increase in harmonics. This freedom in load selection is obtained without wide variation in the internal impedance of the amplifier as the latter is always low with respect to the load impedance. Because of this, the damping effect upon loudspeakers is not sacrificed if the loudspeaker is not correctly matched to the amplifier, and the regulation of the output voltage is always good regardless of the load conditions. These desirable features in the output circuit have been obtained through the judicious use of negative feedback and the inclusion of the entire output transformer in the feedback path. In addition, the amplifier output circuit has the simplified RMA standard 70-volt speaker distribution line connection.

The power amplifiers employ a superior type of phase inverter circuit using a large amount of negative feedback. It assures optimum performance of the power output tubes, over the whole audio frequency range, as well as compensating for wide variations in the performance characteristics of the phase inverter tube.

Typical "Building Block" System

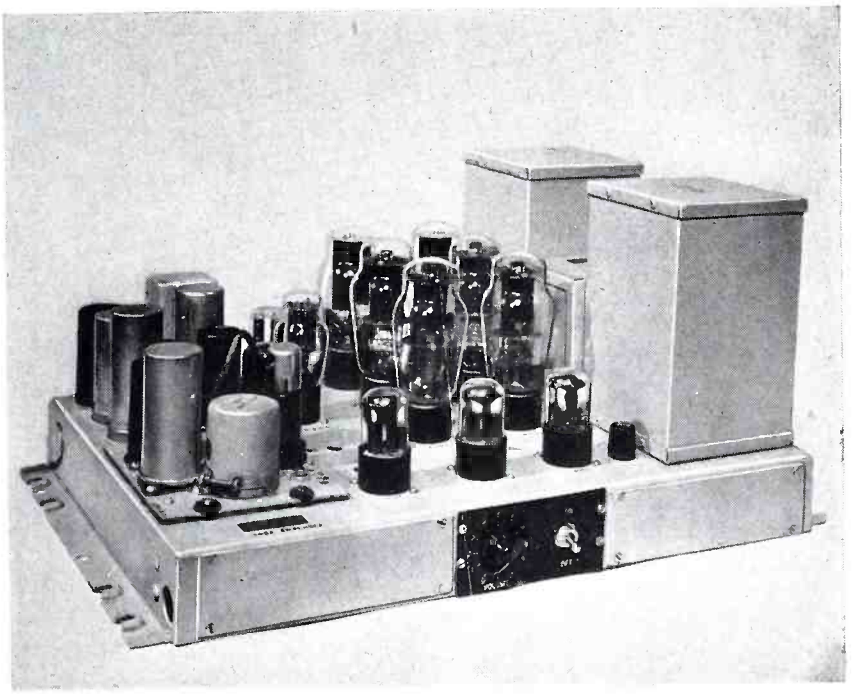
The application of this integrated series of "building block" amplifiers to a multiple channel speech or music distribution system is illustrated in diagram form on page 24. Figure 1 indicates the ease with which a three-channel system, with remote mixing and gain control features, may be constructed. Three 141A Amplifiers are connected as preamplifiers to program sources and fed through individual channel gain controls to a mixer network and then to a master gain control. A 141A Amplifier, mounted on the chassis of the power amplifier (a 142A in this example) is connected after the master gain control and acts as a booster amplifier to raise the level to that required to drive the power amplifier.

The mixer and master gain controls may be located remote from their associated amplifiers. The distance from preamplifiers to remote gain controls may be as long as 300 feet without reducing the rated output level of the preamplifiers. Greater distances between preamplifiers and gain controls can be employed when the output levels of the preamplifiers are slightly restricted.

Multiple Systems Have Compactness

The range of input levels as well as the levels throughout the illustrated system are shown in Figure 2. The solid lines indicate system levels for a 40 db gain setting of the preamplifier. With this setting, the preamplifier can handle a range of input levels varying from −30 to −57 vu and still drive the power amplifier to full output. High level program sources can be adequately handled with this gain adjustment since −30 vu represents the highest level anticipated from even the most efficient microphones. Adequate signal level is maintained throughout the system so that a completely satisfactory signal-to-noise ratio may be easily obtained, while at the same time a volume adjustment range of 27 db in individual channel and master gain controls is provided. The dotted lines show the range in input levels handled by a preamplifier adjusted to have 60 db gain and providing 27 db system volume adjustment range. This gain adjustment of the preamplifier would be employed whenever low level sources were to be handled. A 70 db gain adjustment of the preamplifier

The 142B Amplifier has 25-watt power output, with dual line-level input, master gain control, and includes a 141A as a preamplifier or booster.



For 75 watts of audio power, the 143B Amplifier driven by its associated 141A Preamplifier or a line-level signal has dual input with mixing controls.

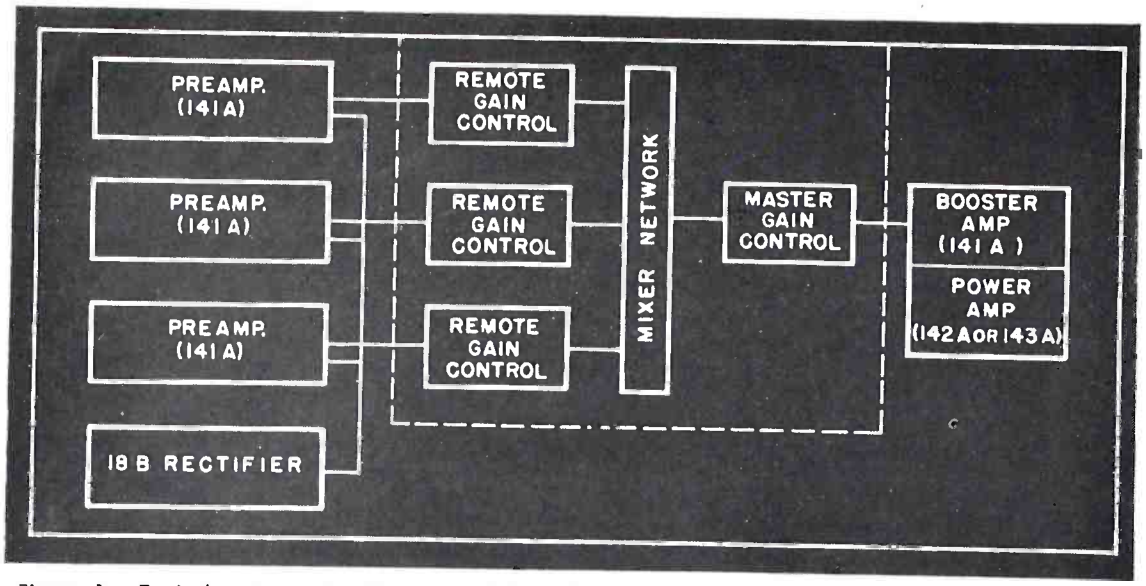


Figure 1 — Typical system using the new building block units. Three 141A Amplifiers are used as pre-amplifiers: the booster is a fourth 141A unit, mounted on the 142A or 143A power amplifier as indicated.

is provided for handling the lowest level input sources.

This system could easily have started out with a single channel consisting only of the 141A Preamplifier and the power amplifier. By the economical addition of three 141A Preamplifiers and an 18B Rectifier for their power supply plus the necessary gain controls, the system has been expanded from a simple single channel to a multiple channel installation, illustrating the economy and flexibility of the system when expansion is desired.

In the event a larger and more complex installation is desired, additional channels may be added at either or both input and output, using the same master control and booster amplifier. The 18B Rectifier shown can furnish sufficient filament and "B" supply power for as many as six 141A Preamplifiers, thus providing additional input channels.

The space saving features of this new series of amplifiers are apparent from their relay rack dimensions. The three preamplifiers require a 5¼ inch height on a standard 19 inch relay rack mounting plate. Power supply for these units may be simply and economically obtained from a Western Electric 18B Rectifier. This unit occupies only 3½ inches of rack space. Thus the combined rack space required for the three preamplifiers and their power supply is only 8¾ inches. The 142A Amplifier, with a booster amplifier mounted on its chassis, occupies a rack space of only 7 inches. If more power is required, a 143A Power Amplifier occupying only 12¼ inches of rack space, can be used.

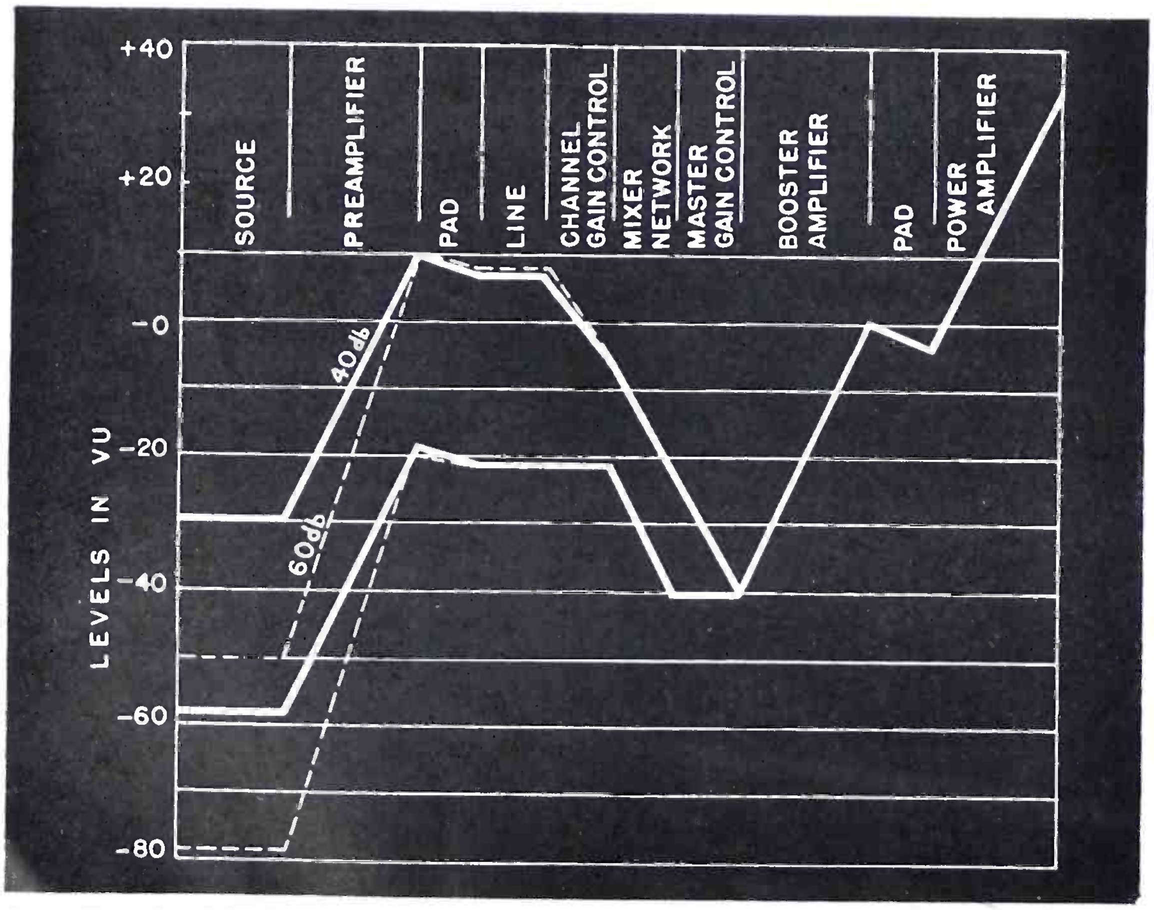


Figure 2 — Signal levels in each section of the typical system of Fig. 1, showing the flexibility of adjustment to match different source levels, and the range of volume adjustment with the gain controls.

Cabinet mounting facilities for the 142 series of amplifiers are also provided. The KS13625 List 3 Cabinet can be employed for the 142A, B and C Amplifiers. A KS13625 List 4 Cabinet is used with the 142D Amplifier.

140A AC-DC Amplifier

The Western Electric 140A Amplifier, in contrast to the above series, is largely a special purpose amplifier for program monitoring and wired program subscribers' services. It was designed to be suitable for all wired program service applications. Since this service is found in both a-c and d-c power districts, realization of the objective could be had only with an ac-dc amplifier design. Careful and painstaking design produced an amplifier unique in that it is entirely free of the troublesome grounding conditions so frequently encountered in applications of ac-dc amplifier sets. The 140A Amplifier requires no special grounding connections, and line grounding conditions or a-c polarity have no effect on the low noise level of this unit.

In order to achieve this freedom of operation, a high degree of longitudinal noise suppression in input circuits is a prime requisite; hence it has been necessary to isolate electrically the circuit within the amplifier—that is, from the secondary of the input transformer to the primary of the output transformer—from all unwanted longitudinal signals. This requires that the input circuit including the input transformer windings be so carefully constructed that the effective capacity from the input circuit to the following active portions of the amplifier literally approaches zero from an audio circuit design viewpoint. This small coupling reduces longitudinal noises picked up on the input circuit over 80 db at normal power frequencies and over 60 db for all frequencies below 1,000 cycles. The isolation and balance are so great that a-c voltage differences of 120 volts can exist between the input circuit and the following active portions of the amplifier without causing appreciable noise in the output of the amplifier.

Easy Matching to Output

The output circuit of this amplifier is also arranged to accommodate a wide range of load conditions in both a-c and d-c power applications. The actual range of load impedances covered are given in the specification sheets on this equipment: in general, loads from 1 to 1,500 ohms may be employed. Judicious use of negative feedback assures low internal output impedance for all load connections. These noteworthy features are obtained without

(Continued on page 34)

An RF Wattmeter and Impedance Monitor for FM Broadcasting

By E. L. Younker

Bell Telephone Laboratories

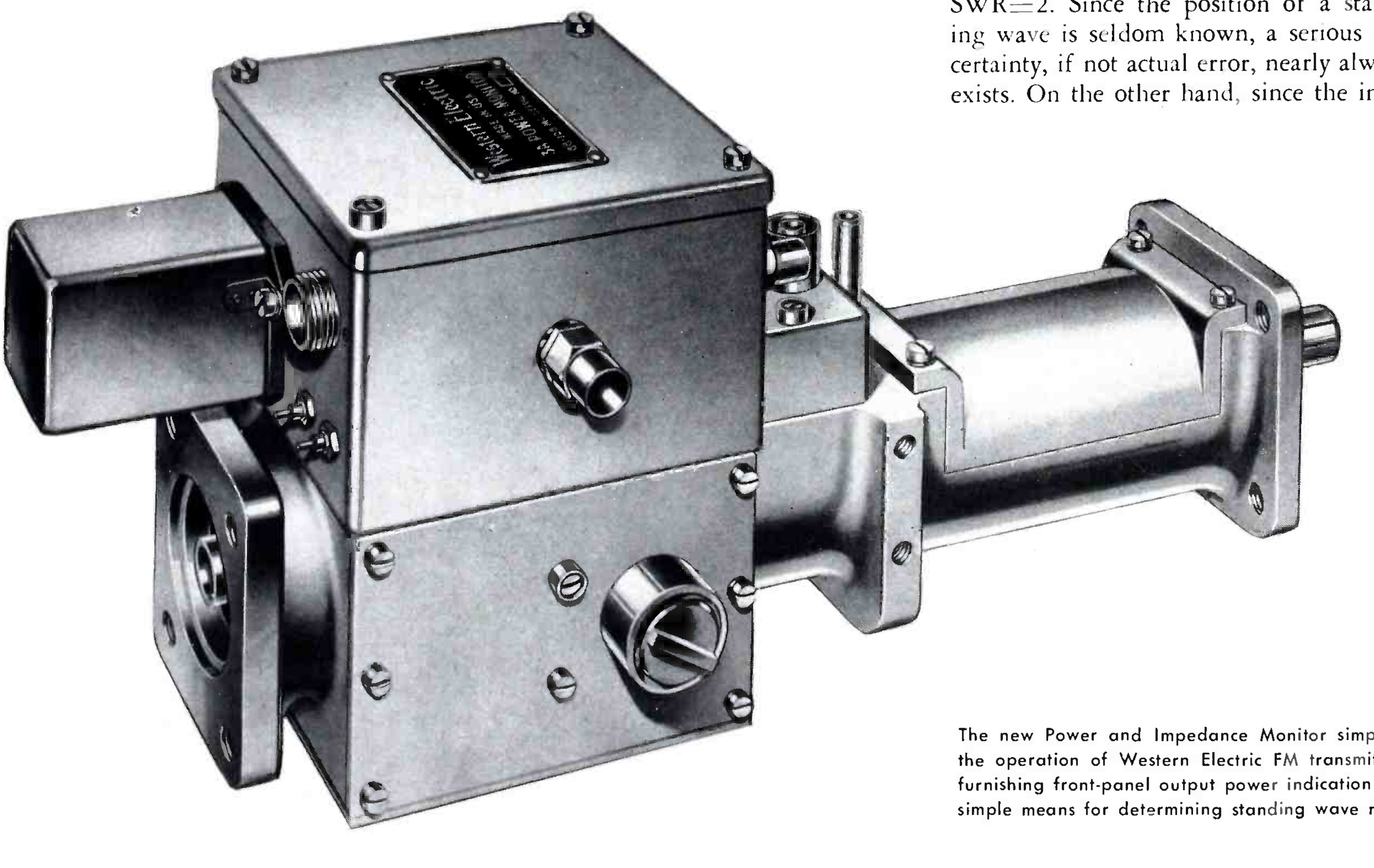
• • First presented to engineers by J. F. Morrison of Bell Telephone Laboratories in a paper before the *IRE* Convention in March 1947, this Wattmeter aroused great interest in the profession. Mr. Younker outlines its function and features in the present article. • •

IN the operation of radio transmitting stations, the amount of power delivered to the antenna, the quality of impedance matching between the antenna and its feeding transmission line, and the presence of adequate protection against damage due to radical changes in transmission line load impedance are of great importance. Imagine a simple device which serves as a radio frequency wattmeter, which gives information concerning the transmission line load impedance, and which also provides protection for the transmitter and transmission line. The Western Electric Power and Impedance Monitor is just such a device. Supplied as standard equipment with Western Electric's 3, 10 and 50 kw FM transmitters, the Monitor will prove a valuable aid in assuring satisfactory station operation, making continuously available to the operator the information he desires concerning the power output of the transmitter and the transmission line terminating impedance.

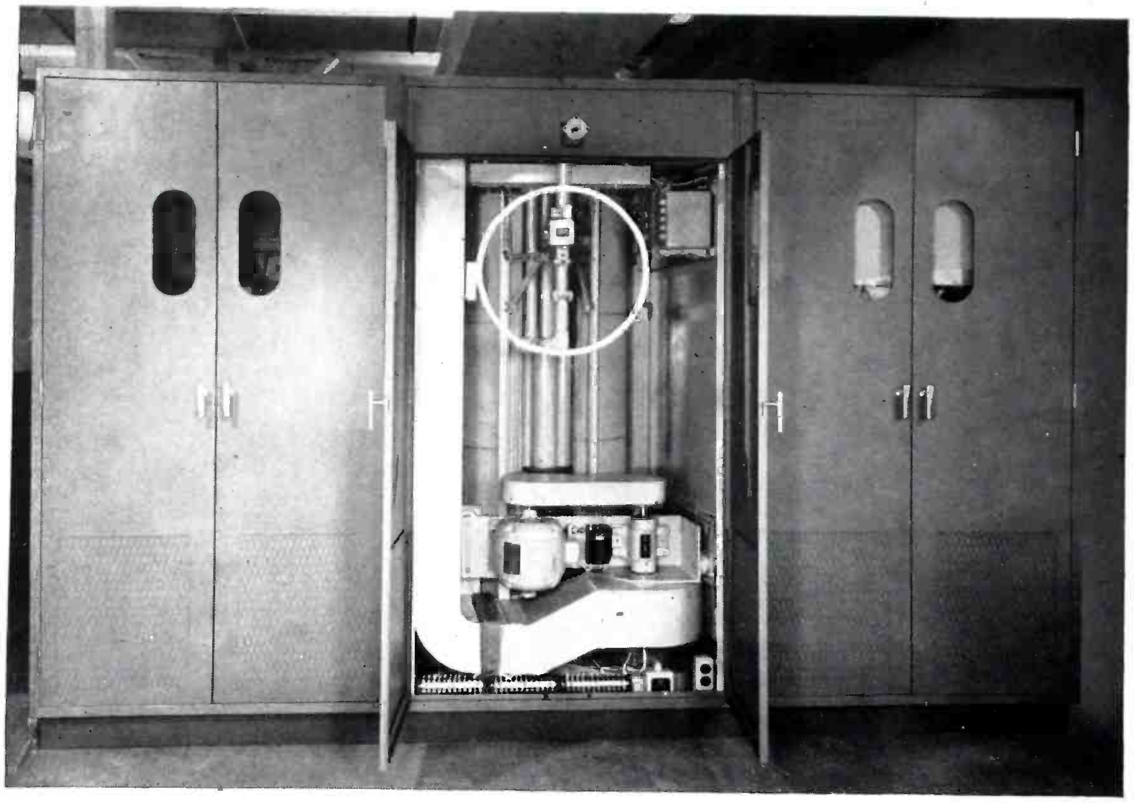
The power delivered by the transmitter may be readily determined by means of the Power and Impedance Monitor even though the input impedance of the antenna is not known. An actual power determination consists simply of taking two readings of a specially calibrated power output meter installed on the transmitter front panel, and subtracting the smaller reading from the larger. The larger power reading is equal to the amount of power incident upon the antenna system (that power which would be absorbed by the system if the antenna impedance matched the line impedance perfectly), while the smaller is equal to the amount of power reflected back to the transmitter by the antenna (such reflection will occur if the antenna impedance does not match the transmission line). The power output meter normally indicates the incident power; by merely depressing a switch, the same meter is made to indicate reflected power.

Greatly Improved Accuracy

Thus the Power Monitor gives an accurate indication of the r-f power actually delivered to the transmission line and antenna system, regardless of the magnitude of the transmission line standing wave ratio. The commonly used single probe voltmeter or ammeter method has a large inherent uncertainty in the presence of a standing wave of unknown phase and magnitude. The possible error in power determination as a function of standing wave ratio (SWR) is shown by curves A and B in Fig. 1. For example, if the standing wave ratio is two, the computed power will be twice the true power if the probe is at a maximum position, while the computed power will be one-half the true power if the probe is at a minimum position. If the probe does not fall at a maximum or minimum point, the error will lie on the vertical line between curves A and B which intersects the abscissa at SWR=2. Since the position of a standing wave is seldom known, a serious uncertainty, if not actual error, nearly always exists. On the other hand, since the indi-

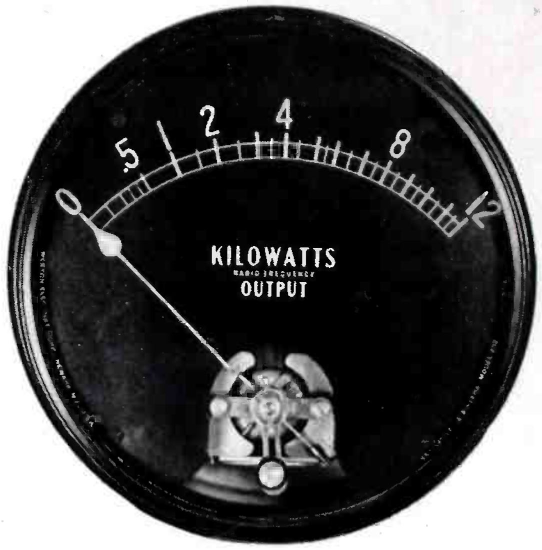


The new Power and Impedance Monitor simplifies the operation of Western Electric FM transmitters, furnishing front-panel output power indication and simple means for determining standing wave ratio.



Left: Rear view of Western Electric 10 KW FM transmitter shows Power Monitor installed near top of center section for easy connection to output line.

Below: Directly calibrated output meter on front panel reads power being fed to antenna system and provides data for determining standing wave ratio.

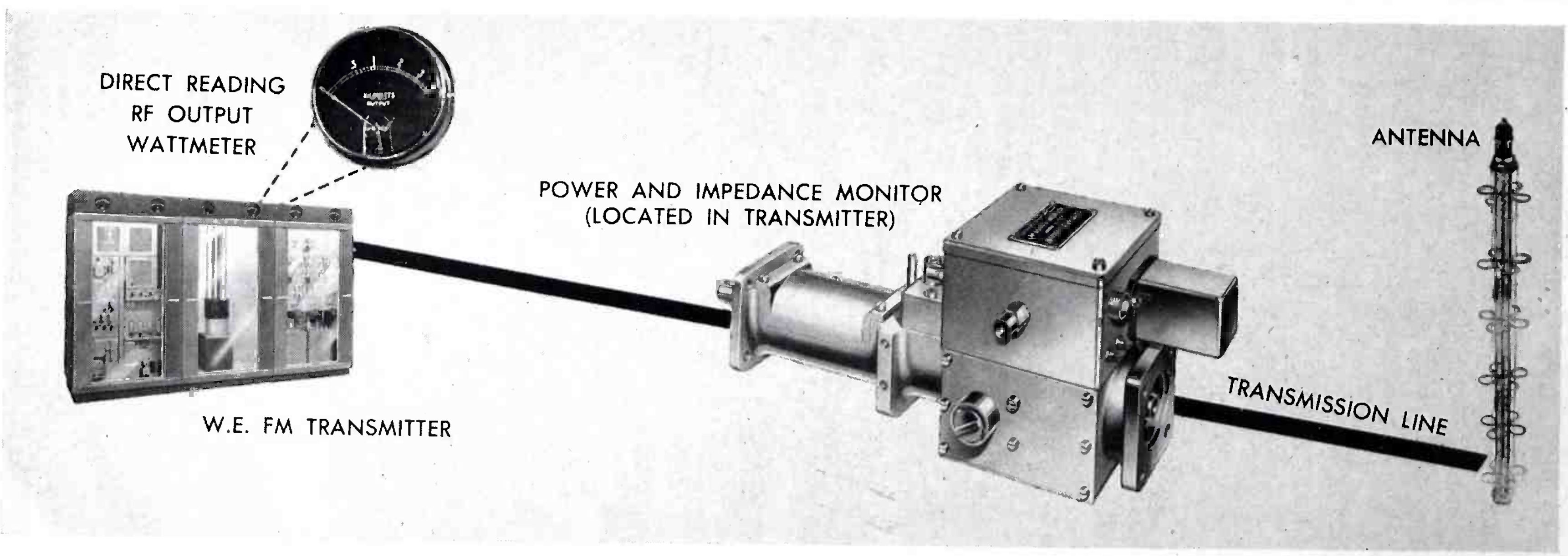


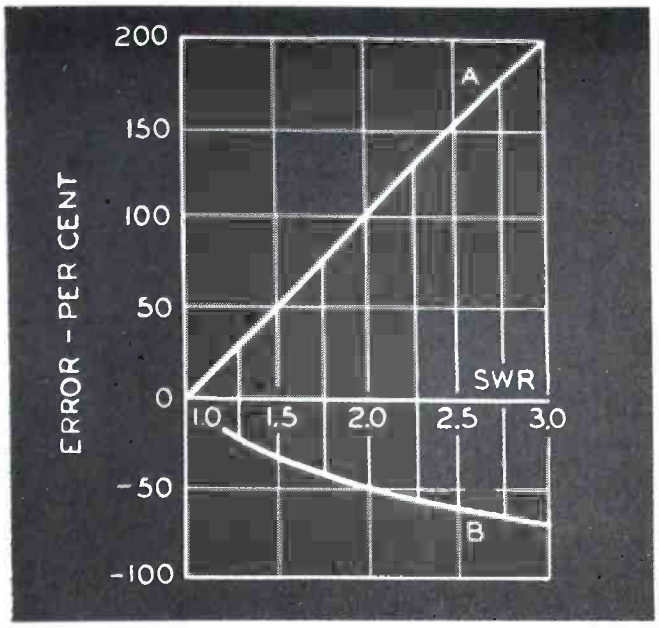
cation of the Power Monitor has been made insensitive to the phase of the standing wave by taking both the current and the voltage samples at the same point in the line, the error in power determination with the Monitor is very small, regardless of the standing wave ratio. Experimental measurements have shown that the measured power agrees with the true power to within 5 per cent for standing wave ratios up to 2.5 and to within 10 per cent for standing wave ratios from 2.5 to 6.

Measurement of a transmission line impedance mismatch is equally simple with the Monitor. The reflected power reading of the power output meter is in itself a measure of the line mismatch; this reading will be zero for a perfectly matched line and should not exceed about 5 per cent of the incident power for a reasonably well-matched line. The incident and reflected powers are intimately related to the standing wave existing on the transmission line and therefore the two meter readings mentioned above provide sufficient information for the determination of the standing wave ratio. The standing wave ratio is in practice determined by reference to a table or chart which relates standing wave ratio to incident and reflected power. The Power Monitor's advantages of simplicity and speed are apparent when one recalls the labor of making standing wave measurements with the "slotted-line section", where a voltage or current probe must be moved along the transmission line for at least a quarter wavelength (approximately 2½ feet at 100 mc).

A circuit is incorporated in the Monitor which protects the transmitter against the harmful effects of large changes in the load impedance. It also protects the transmission line against arcs, initiated by lightning or other causes, and sustained by r-f power derived from the transmitter. This protective ability of the Power Monitor is based on the fact that as the transmission line mismatch increases, the amount of reflected power also increases. A small d-c current, which is proportional to the reflected power, flows through the winding of a relay. The sensitivity of the relay is adjusted so that operation will occur whenever the reflected power exceeds a predetermined value. Operation of the relay applies a cut-off bias to two frequency doubler stages in the transmitter, thus interrupting the r-f output of the transmitter. With no r-f output from the transmitter there is no reflected power, and if the trouble is cleared, normal operation is restored. The duration of the off time is 1/10 second. A small signal light, which continues to glow until reset by the operator, indicates that the interruption was caused by a high power

This block schematic shows how the new Power and Impedance Monitor is applied to the operation of Western Electric's FM transmitters. The Monitor is installed in the transmitter just ahead of output connection to transmission line and the meter, on the transmitter front panel, reads output power in kilowatts.





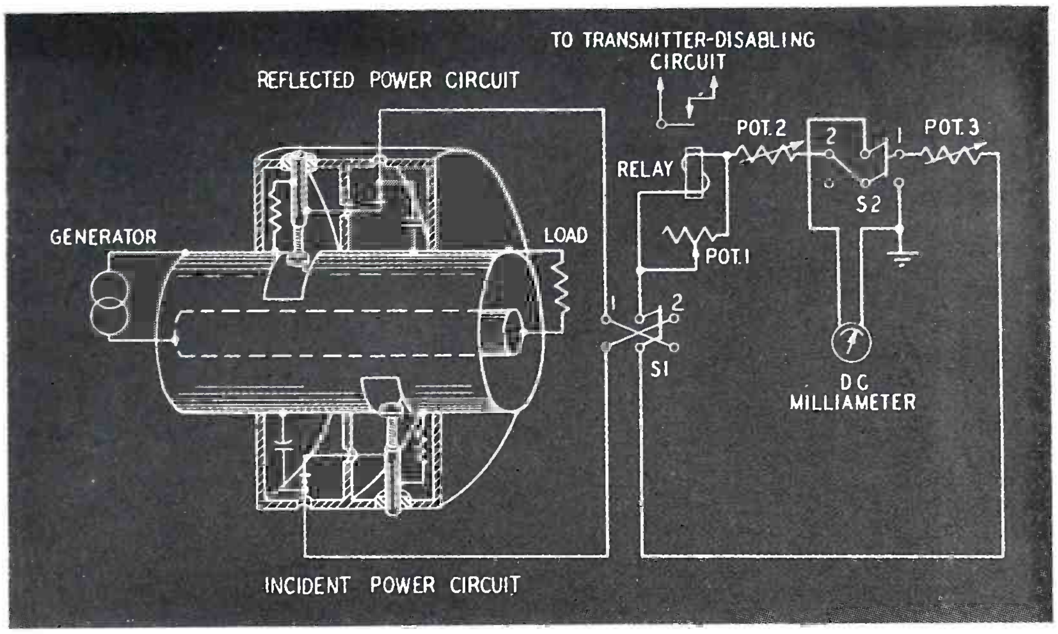


Figure 1 — The inherent error in power measurement with the single probe method, plotted against standing wave ratio.

Fig. 2 — Diagram of Power Monitor shows how inherent error of measurement is eliminated by arranging pickup of simultaneous voltage and current samples at a fixed point in the coaxial line.

reflection on the line.

An internal view of one section of the Monitor proper is shown in the photograph of an experimental model in Fig. 3. The most interesting details in this photograph are (1) the slot in the outer conductor of the coaxial line, and (2) the circular plate suspended in the slot. These elements constitute current and voltage pickups. By combining the outputs of such pickups properly, the power incident upon the antenna or the power reflected from the antenna may be measured.

Fig. 2 shows how voltage and current pickups are used in the Power Monitor. Two circuits (one to measure incident power, the other to measure reflected power) are arranged back to back on a coaxial line inside a shielded enclosure. These circuits are alike except that in the incident power circuit the fixed resistor is connected to the load side of the slot, while in the reflected power circuit the resistor is connected to the generator side of the slot. Each circuit is an independent unit; they are placed near each other only for mechanical convenience. In the circuit which measures incident power, an r-f voltage due to the voltage and current pickups is impressed upon a crystal rectifier. The rectified current from the crystal flows through potentiometer "Pot. 3" and a d-c milliammeter. Switches S1 and S2 are normally in position 1. Switch S1 is used only during calibration of the Power Monitor; Switch S2 is used during operation of the transmitter to connect the power output meter to either the incident or the reflected power circuit. In the circuit which measures reflected power, a voltage due to the other set of voltage and current pickups is impressed upon a crystal rectifier. The rectified current from this crystal flows through the winding of a sensitive relay and the potentiometer "Pot. 2" to ground. This rectified current may be made to flow through the milliammeter by throwing Switch S2 to position 2. It should be noted here that a rectified current proportional to the amount of power reflected by the antenna flows through the relay winding regardless of whether or not the reflected power is being indicated on the meter. Thus the protective relay is operative at all times.

Convenient Calibration

The voltage pickups in the r-f circuits of Figure 2 are made variable to permit the adjustment of the magnitude of the line voltage sample relative to the line current sample. When these voltage samples which are impressed upon the crystal rectifiers are properly proportioned, the output of the incident power crystal is independent of any energy reflected by the antenna, and the output of the reflected power crystal is independent of energy

(Continued on page 30)

Figure 3 — Interior of experimental model of Monitor, showing slot in the coaxial conductor, and adjustable disc, for pickup of voltage and current samples.

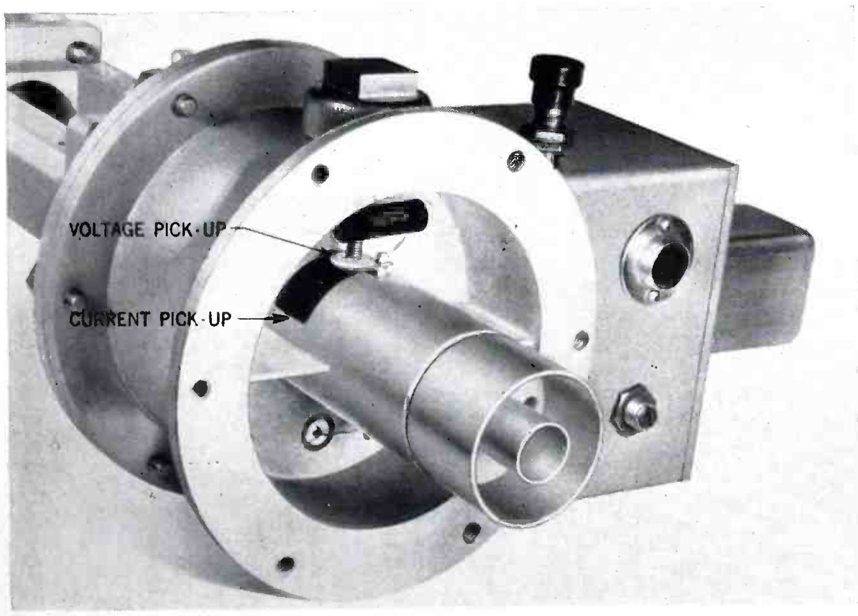
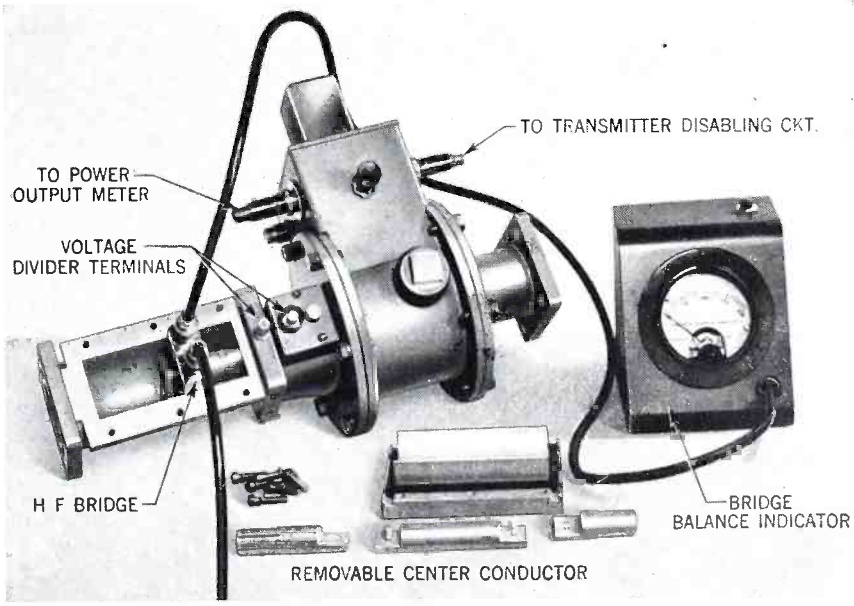


Figure 4 — Experimental model of Monitor with port opened and section of inner conductor removed, for insertion of HF Bridge in initial antenna tuning.

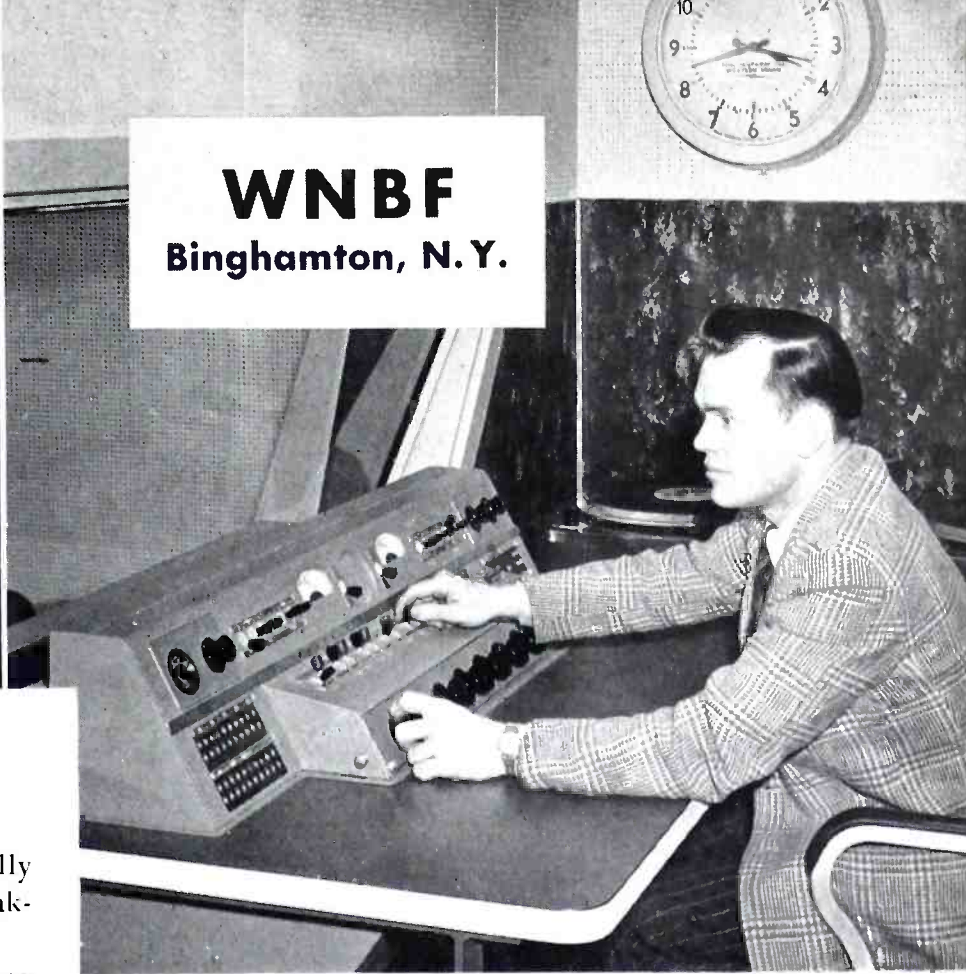


25B CONSOLES

HERE are eleven of the more than 150 new Western Electric 25B Speech Input Consoles which have been shipped to stations all over the country.

Designed by Bell Telephone Laboratories, the 25B can handle either AM or FM programs or both simultaneously through its two main amplifier channels. It incorporates a separate monitor and cueing channel.

The equipment has a seven channel mixer: four mixers have pre amplifiers for eight connected microphones (four operate simultane



ON THE JOB

ously); three mixers accept line level inputs, or by using externally mounted preamplifiers three additional microphones can be used making a total of seven microphones simultaneously.

Its characteristics are as follows: frequency response ±1 db 50 to 15,000 cycles; harmonic distortion, less than 1 per cent at line level output; noise 70 db below peak signal.

The controls are arranged for operating flexibility and convenience. The console is wired for plug-in cable connection and all parts are readily accessible for inspection and maintenance.

Quality Loudspeakers

(Continued from page 10)

the smallest up to the mammoth movie palaces seating several thousand persons.

Each speaker is supplied in a baffle which mounts, at the top, the KS-12024 or KS-12025 high frequency horn, used singly or in combinations to give horizontal high frequency coverage from 50 degrees to 100 degrees. The high frequency horns are driven by a new receiver, the 713B, especially designed for these high efficiency systems.

The baffle supplied with each speaker has built into it the low frequency horn, which is driven by one or more of the 754A units. Also included in the baffle is an air chamber of optimum proportions in back of the low frequency speakers, which together with the horn establishes a smooth low frequency characteristic. The necessary dividing network is built into each unit. Thus each system is a complete, integrally designed unit, using exponential horns and special high efficiency drivers for both low and high frequency ranges, fully equipped to project the highest quality of sound strictly in accordance with motion picture requirements.

The following table shows the minimum power requirements for theatre loudspeakers as recommended by the Research Council of the Academy of Motion Picture Arts and Sciences:

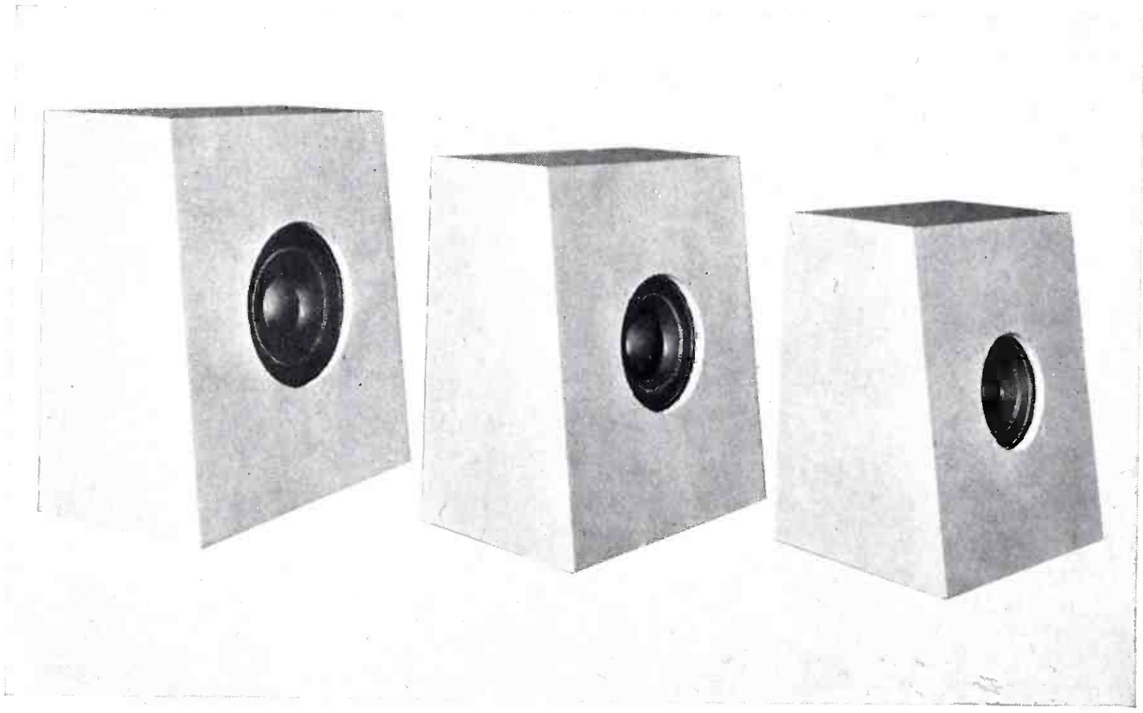
Power Capacity Watts	Seating Capacity
15	750
30	1400
60	2800
120	5600

The proper horizontal distribution of high frequencies will depend on a number of variables, including the acoustic treatment of the walls, ceiling, etc. In general, the long narrow theatres will use the KS-12024 horn for 50 degree horizontal distribution; the average square-shaped theatres use the KS-12025 horn for 80 degree distribution; and the theatres relatively very short from front to back, such as the typical legitimate stage theatre, use two KS-12024 horns for 100 degree distribution.

For portable sound motion picture projectors, the direct radiator types are recommended. They are easily mounted in the standard "carrying case" enclosures which provide portability and ready setting up wherever the projector is to be used. The ten-inch 756A with 20 watts input capacity will meet the great majority of portable motion picture projector needs, giving adequate coverage of spaces seating up to several hundred people. For projectors intended for use in the home, the 755A will provide the necessary sound levels at a power input well within its capacity.

Special Applications

The story of the adaptability of the new line of speakers to modern sound reproduction needs is merely outlined in the foregoing discussions of the major fields of use. The mechanical convenience of the speakers, their small size relative to power capacity, their greatly reduced mounting space requirements, are design factors which make them attractive in nearly all of the rapidly multiplying uses of reproduced sound. Their superb quality of reproduction is essential wherever listener acceptance and pleasure are important to the success of a sound system. To the designer, manufacturer, sound engineer, home builder — whatever your special needs for a loudspeaker, study the new line of Western Electric speakers. You will find a speaker to do a better job than anything you have had before.



This type of sloping front utility cabinet, shown for the 12-inch, 10-inch and 8-inch speakers, is recommended for use with the new Western Electric direct radiators. For dimensions of the cabinets, see page 9.

RF Wattmeter

(Continued from page 27)

incident upon the antenna. The balance adjustment of the voltage pickup is independent of frequency; for this reason one factory adjustment of the voltage pickup is all that is required, no matter at what frequency in the FM band the Power Monitor is used.

The Monitor is calibrated as a wattmeter by determining the amount of power dissipated in a matched load, and then adjusting the potentiometer in the d-c circuit (Fig. 2) to obtain the correct indication on the power output meter. The power output meter is a d-c milliammeter, mounted on the transmitter front panel for the convenience of the operator, which has been calibrated in kilowatts according to the experimentally determined relation between r-f power and rectified current of the germanium crystal rectifiers used in the Monitor. The kind of scale obtained from this calibration is illustrated by the photograph on page 26, where the power output meter for a 10 kw transmitter is shown. The fact that the scale is expanded in the lower power region is significant because good accuracy is desired in the measurement of low (reflected) as well as high (incident) powers.

Two auxiliary devices included in the Monitor deserve particular mention. The High Frequency Impedance Bridge is provided to give a speedy and simple indication of antenna mismatch during adjustment of the antenna input impedance. A removable section of inner conductor and a port in the outer conductor of the Monitor facilitate the insertion of the Impedance Bridge, as shown in Fig. 4. A small amount of r-f power at the operating frequency is supplied through the input jack of the Impedance Bridge and adjustments of the antenna input impedance are made until the bridge is balanced (zero meter reading). The Impedance Bridge consists of three arms of a Wheatstone bridge and a crystal rectifier to indicate the degree of bridge unbalance. When it is inserted into a coaxial transmission line, the line input impedance forms the fourth arm of the Wheatstone bridge. Since each of the resistance arms contained in the Impedance Bridge is equal to the characteristic impedance of the line, the line input impedance must also equal the characteristic impedance when the bridge is balanced.

At the right of the Impedance Bridge in Fig. 4 are the output terminals of a capacitance voltage divider which has been built into the Power Monitor. This voltage divider, which provides a 100:1 reduction between the line voltage and the divider output voltage, affords a convenient range for a vacuum tube voltmeter if for any reason it is desired to measure the line voltage. It permits the insertion of a voltmeter without affecting the line impedance or power, as would be the case if a voltmeter having 5 to 10 $\mu\mu$f input capacitance were connected directly to the inner conductor.

The improved accuracy of power measurement, the increased speed and convenience of transmission line mismatch determinations, and the provision of a protective device, make the Power and Impedance Monitor a valuable instrument in the new Western Electric FM transmitters.

Sound Reproduction

(Continued from page 5)

These are the functions that have made the reproduction of sound a part of the everyday life of every one of us, and made deep changes in our way of doing business, our cultural interests, our social activities. As a specialized tool in engineering, business, education, etc., reproduced sound has an endless number of other uses:

The monitoring of program material in radio and recording studios; intercommunication systems in offices, factories, etc.; dictation recording and playback instruments; announcing and talkback systems in freightyards for coordinating and speeding the assembly of trains; advertising from aircraft; the study of speech characteristic in the laboratory or the language class; correction of hearing deficiencies; police warning systems and control of crowds or traffic; battle-announcing, general orders on ships of war; self-analysis for the music student;

—the list could go on, even to the recently described equipment for luring male mosquitos to their death with a recording that simulates the mating call of the female!

Early Triumphs

The universal significance, the endless versatility of the reproduction of sound were to some extent understood at its very birth seventy years ago. Alexander Graham Bell, in ushering in the telephone, could predict that it would one day link the Nation together from coast to coast in instantaneous spoken communication.

Thomas Edison wrote as follows after listening to the quavery voice of his first tinfoil phonograph in the fall of 1877:

"For, indeed, the possibilities are so illimitable and the probabilities so numerous that the writer, though subject to the influence of familiar contact, is himself in somewhat chaotic condition of mind as to where to draw the dividing line between the possible and the probable."

Why did the reproduction of sound, aside from the telephone, take seventy years to reach the importance that was inherent in it from the beginning? The answer is, of course, that technical effectiveness was lacking, again aside from the telephone, which early achieved an adequate technique. The technical problem was much more complex than the early workers in the field could have known. A few highlights from the history of the technical development of sound reproduction will show how each advance in power and faithfulness of reproduction has opened new fields of application.

The phonograph industry, the first great success of reproduced sound after the telephone, was put on a solid commercial basis, beginning about 1905, with the instrument as developed by Edison, Chichester Bell and Sumner Tainter, Berliner, Eldridge Johnson and others—an instrument that was used without fundamental change for twenty years, right up to the introduction of electrical reproduction in 1925. The "acoustic" phonograph had so many limitations that its success is a real tribute to the importance of the reproduction of sound. These limitations were:

Drastically limited power for both recording and reproduction;

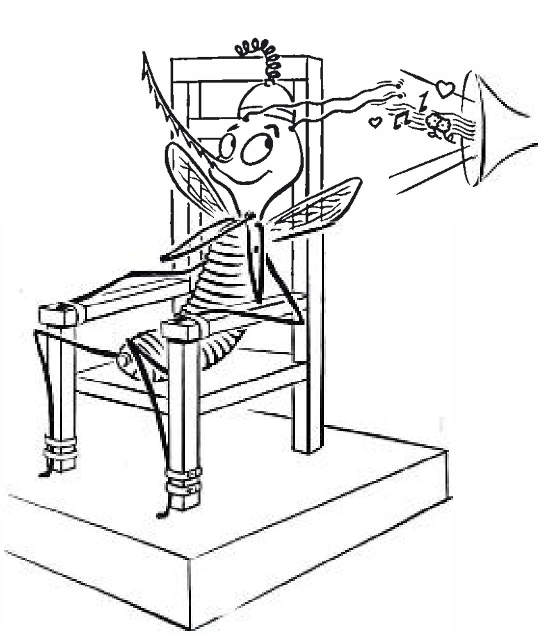
No methods of controlling volume;

Frequency response a fraction of that required for faithful reproduction;

Distortion at very high levels;

System inflexible and inconvenient in physical layout at both recording and reproducing end.

Most important of all, there was no engineering understanding of the characteristics required for faithful reproduction, no methods for measuring accurately such characteristics had they been understood, and no real engineering art for improving the performance of mechanical-acoustic devices.



Sound reproduction lures this lovesick mosquito to his death. A recording of the "mating call" of the mosquito by Cornell scientists brings the unsuspecting male to a quick and blissful electrocution.

All these deficiencies are symbolized by the familiar pictures of the sweating group of musicians closely huddled around the mouth of the recording horn, a long conical monstrosity that projected through the wall into the adjoining recording room, where the cutting of the master was controlled more with cabalistic incantations than with engineering techniques of the kind available today. With the vast, almost overpowering success of the phonograph of today before us, it is easier to understand that the acoustic phonograph, successful as it was, failed in a mighty opportunity because of its technical limitations.

Electrical Recording

The series of developments in the reproduction of sound that culminated dramatically in the years 1920-1925 completely broke this log jam, and brought in not only electrical recording and reproduction, but two new applications that became the greatest fields of reproduced sound—the talking movies and the radio. At the same time a series of early Bell Telephone experiments in "public address" came to fruition with the emergence of outdoor high level sound as an important field of use. Here is a summary of the events and advances that made up this turning point in the history of the reproduction of sound:

1919-1925: Bell Telephone Laboratories developed *electrical recording and reproduction* originally as a research tool for the study of speech. Here at last was power, and even more important, a clear engineering conception of the requirements for faithful reproduction of music and speech. The work of Fletcher, Maxfield, Harrison and others of Bell Laboratories had indicated that, for their research objectives, their long-range goal should be a system capable of reproducing from *30 to 10,000 cycles,* a specification that even today connotes something very near the ultimate in frequency response requirements for speech and music. The first system developed did not, nor was it expected to, reach this goal in a single leap. But its range up to about 6,000 cycles was so much better than the "acoustic" system that a revolution in recording and reproduction techniques was bound to occur.

1919: Public address reached toward its present stature with its demonstration of power at Victory Way, the mammoth victory celebration in New York City. One hundred and thirteen loudspeakers were actuated by a single telephone transmitter, as well as by signals from telephone lines and from phonograph records, to link hundreds of thousands of people together in an event of national interest.

1921: Radio began to speak directly to the American public at large as commercial broadcasting opened its spectacular career. It is said that an engineer who helped to set up one of the early broadcast stations quit his in-on-the-ground-floor job because he saw "no future in broadcasting." No record exists of his statements a few years later, when radio had won its place as the great American home entertainer so completely that the once mighty phonograph industry was laid in the dust. It is important to note that early radio, crude as it was, won this victory with a superior quality of reproduction.

1922: Maxfield and Harrison announced their *application of electrical network theory to mechanical analogues* in vibrating systems, laying the foundation for the modern art of electro-acoustic development. This technique of design, which was found necessary to develop the cutters, pickups and loudspeakers for the new wider range reproduction system, was just as important as the electrical recording system itself. Here, at last, was the means for controlling and improving the design characteristics of a sound reproduction device, so that it would more nearly satisfy the requirements for faithful reproduction.

1925: The phonograph industry, by now well aware that a new era had opened, adopted Bell Laboratories' electrical recording system as the first step in a long comeback fight. Electrical reproduction was introduced after an interim period in which the Maxfield and Harrison technique was applied to the improvement of the acoustic reproducer, producing the well-remembered "Orthophonic".

1926: Sound came to the movies. Here again Bell Laboratories' speech research tool, electrical recording, brought a revolution to an entertainment industry. The dream of using sound with motion pictures was as old as Edison's first experiments in movie production. Workers in the field saw immediately that electrical recording would make the dream real.

The dependence of three major industries on reproduced sound, and the newly crystallized engineering concepts and design techniques opened the floodgates. New developments in technique followed rapidly. The repeated pattern of change during this period is that of new responsibilities for the reproduction of sound demanding advances in technique, which advances in turn open new fields of use.

A whole new concept of loudspeaker design, for instance, started with the Western Electric 555 receiver, developed to meet the moving pictures' urgent demand for a high-level, wider range speaker to bring the realism of reproduction necessary when sight and sound work together. This speaker had good response to about 7,000 cycles and opened the way toward high quality distribution of music in large areas. The expansion of sound reproduction into political campaigns and World's Fairs on a large scale brought the development of high-power amplifiers of higher quality, and of much more flexible methods of control. These refinements brought new capabilities for sound reproduction in large scale dramatic productions, circuses, etc.

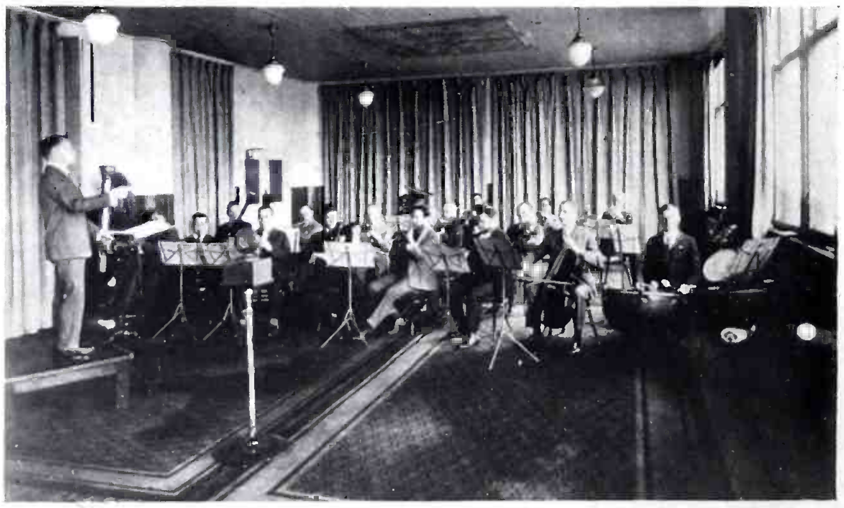
The radio industry has pushed the development of microphones of increasingly higher quality throughout its history. These finer microphones proved to be one of the important keys opening concert hall "volume enhancement" as a going technique. Stereophonic sound was developed to further the understanding of human reactions to reproduced sound. It made possible really effective use of sound in great outdoor pageants, such as the famous Texas Centennial in 1937, where the apparent source of the sound was made to follow actors moving over a wide area.

A detailed history of the technical development of the reproduction of sound during this period would lengthen this list to impressive proportions. This constantly repeated opening of new horizons with advances in technique holds the most important lesson for all of us. When we contrast the limited usefulness of the reproduction of sound in the pre-1920 period with its fantastically expanding power, importance, and versatility today, it is absolutely clear that greater refinement of technique, greater faithfulness in reproduction are the basic keys to this success story.

Many forces are now at work to make it certain that this process will continue, that the reproduction of sound is now expanding into an even larger future. World War II brought a vastly accelerated pace to development of every phase of the technique. Loudspeakers, amplifiers, all forms of recording were advanced to meet the urgent demands of high power beach announcing systems, underwater sonar equipment, battle announcing and communication systems on warships, high level sound projectors for psychological warfare, and many applications still covered by secrecy provisions. This intensive development, coupled to the commercial advances of the past decade, has given the reproduction of sound by far the greatest flexibility and refinement of its history, although the full measure of this refinement has not been applied throughout the industry. Contrast the severely limited effectiveness of sound reproduction in the period of the acoustic phonograph, with its powers today:

The whole frequency range necessary for complete faithfulness can be recorded, transmitted, reproduced;

In the pre-electrical recording era, musicians crowded about conical recording horn and used horn-equipped violins for increased power to make a recording.



In the post-electrical recording era, this picture of an early recording session shows how microphone sensitivity brought freedom to recording group.

- Amplifier technique has advanced to the point where power at any level is conveniently available, making possible the use of a really effective dynamic range. Much higher power capacities are standard practice today;
- High gain, flexible arrangement, easy control also have been achieved in the design of the modern amplifier;
- Loudspeakers, reproducers, microphones, as well as amplifiers, are now, at their best, instruments capable of near perfect faithfulness;
- This faithfulness of reproduction has introduced design factors not considered a decade ago. For example, the widespread use of degenerative feedback to reduce distortion, noise and instability, requires that the whole system be controlled for several octaves above and below the band over which excellent performance is required. This means that with negative feedback, if high quality performance is wanted over the band 30 to 15,000 cycles, the performance of all elements must be carefully controlled from the subaudible to the lower radio frequencies, or at least from 7 to 60,000 cycles. In many applications this band width may be at least double. The awareness of the critical nature of the distortion level and the extent to which the reduction of distortion has been attained can be judged by the requirements of measuring instruments. A good distortion meter today must be capable of measuring at least one-tenth of one per cent harmonic distortion, a level considered absolutely negligible a short time ago. Intermodulation, which up to a few years ago was only considered in certain limited applications, is now recognized as important in many aspects of high quality systems;
- Techniques of installation and use have advanced to give much greater effectiveness to sound systems. For instance, the practice of using multiple speakers operating individually at low levels in music distribution aids each speaker in projecting distortion-free sound, produces an even distribution of sound energy that is not uncomfortable in level at any point, and raises the efficiency of the system by using wire, rather than the attenuating acoustic medium, to carry energy to the point of use;
- High realism of reproduction opens the way to volume reinforcement in concerts, churches, etc., which does not distract attention from the actual source of the music or speech. Older systems actually pushed the speaker or musicians further away from the listener and focused his attention on the loudspeakers, rather than the performer. Today it is possible to reproduce sound that allows the listener to identify what he hears completely with the musicians or speakers in front of his eyes. Psychologically, this *brings the performer up to the listener;*
- The proper use and control of "liveness", which is of paramount importance in making reproduced music really enjoyable, is at last gaining widespread acceptance in the industry, after a checkered career going back to the very beginning of electrical reproduction. It is possible now to calculate closely the amount of reverberation producing the most desirable effects with each kind of music, and to achieve such a "liveness factor" with simple mixing and microphone placement techniques;
- A corollary and equally important benefit arising from liveness control is the creation of perspective, of a powerful sense of a third dimension in reproduced sound. The apparent source of any sound can be made to advance toward the listener, or retreat from him, *at the will of the operator*. This not only adds to realism in the reproduction of music, but has endless dramatic potentialities in the movies, in pageants, plays, etc.

The very existence of this refinement of technique which is available to the designer is a potent force making for the fuller extension and use of higher quality sound in each industry and application, considering the highly competitive nature of the field. An equally important force is the development of public demand for better reproduction in the increasing number of daily contacts between the individual and reproduced sound. The whole logic of the history of sound reproduction, as already outlined in this article, is that when a really better, more faithful technique of reproduction is made available, the public eventually demands that all similar services come up to the new standard.

Public appreciation of the benefits of really faithful reproduction has been growing rapidly in the last few years, and promises to be far greater in the near future. The vast growth in taste for and knowledge of fine music is a most potent force behind the development of higher quality in sound reproduction. It is an axiom that the serious collector of phonograph records—and he is numbered now in the millions—is a man intensely alive to improvements in quality of reproduction. The very fact that millions of people now regularly find deep pleasure and satisfaction in concerts of serious music indicates that a larger and larger section of the public has acquired a personal knowledge of *how music really sounds*.

And the public will be given more and more opportunity to hear realistic, faithful reproduction which can be used as a standard of comparison. Television, like the movies, has found that sight and sound blend harmoniously together only when the sound seems to be a faithful representation of the enacted scene. FM broadcasting, with its wide frequency range, low noise level and lack of interference will be another important source of education for the listening public. The current spread of high quality volume reinforcement systems in churches, concert halls, etc., demonstrates to the listener what faithfulness of reproduction can do to make lectures, church services, concerts, more enjoyable. The mushrooming uses of "background music" in office, factory, restaurant, etc., depend to a large extent on the proven connection between faithful reproduction and the pleasurable state of mind of the patron or worker.

All this public experience with high quality reproduction will have its inevitable effect. The reproduction of sound, already in a position of outstanding importance in our society, is going on to even greater usefulness, more varied application. And the force that keeps new doors opening, that widens public acceptance, that gives the technique its endless and fascinating resourcefulness, is the steady growth toward the highest quality of reproduction that the technique makes possible.

Inspiration or Apparition

Courtesy Frequency Modulation Business

"My dear, where did you find that lovely four-bay hat?"

New Line of Amplifiers

(Continued from page 24)

reduction in rated power output or increase in harmonics.

As previously stated, this equipment is intended primarily for wire program service; hence it is designed to operate directly from telephone lines and meets all the requirements imposed by the telephone companies on equipment so operated. Thus, wherever local telephone company practices permit, this unit may be directly connected to the telephone line and requires no separate isolating coil. In addition, this amplifier complies with all the protective requirements of the Underwriters Laboratories and bears their stamp of approval. Its use on the subscriber's premises in no way jeopardizes the subscriber's fire insurance protection.

The 140A Amplifier is designed for either relay rack or cabinet mounting. This amplifier, mounted in its cabinet, is coded the 1140A Amplifier. Its use in this form is recommended for the usual subscriber's installation as no additional mounting facilities are required. When so mounted, it is light in weight and can be used as either fixed or portable equipment.

Detailed specification sheets on these new amplifiers are now available from the Graybar Electric Company. They deserve the careful attention of customers intending to install new sound distribution systems or provide wire program service to new subscribers.

A Good Loudspeaker

(Continued from page 13)

phragm adapted to use in outdoor installations.

Two exponential low frequency horns have been designed for these systems, one to accommodate a single 12-inch driver, and one for two 12-inch drivers working side by side. Response down to 40 cycles allows reproduction of the lowest frequencies required in high quality, high level sound systems. The mouths of the low frequency horns are designed for proper distribution of energy of the whole range of frequencies covered by the horns.

The air chamber in back of the low frequency drivers is completely enclosed and provides proper acoustic loading for the low frequency response described. This closed arrangement avoids the raggedness in the low frequency characteristic which often results from using a portion of the back radiation to reinforce the bass response.

The complete systems are furnished in various combinations of the low frequency horns and drivers with the KS-12024 and KS-12025 horns and 713B high frequency receiver, to form loudspeaker systems covering every requirement for high level, wide range reproduction.

The mechanical characteristics of the new high-level systems have been carefully considered to reduce to a minimum the size, weight, and space requirements of each system. As a result, each one of the new models offers a saving in weight and size over speakers of comparable power capacity formerly available.

Finally, in both the direct radiator speakers and the dual unit systems, every single feature of the design has been chosen for the maximum ease of manufacture consistent with the over-all objectives of the design. This means that the speakers will not cost more than their qualities demand. They have been designed, not only for superior reproduction and mechanical convenience, but also for full value to the user.

Manufacturing Processes

In the new Radio Shops at Burlington, North Carolina, Western Electric's new loudspeakers are moving down the assembly line in a production process set up with every safeguard of inspection and quality control to insure that each speaker embodies to the full the high qualities of Bell Telephone Laboratories' design.

The vital dimensional accuracy of the air gap and voice coil parts is assured by maintaining close tolerances of these parts. Permanent rigidity and high mechanical strength result from actually welding the magnetic parts together, avoiding any form of soldering of the magnetic gap structure to the frame.

A specially designed machine has been developed to wind voice coils which have permanent uniformity of dimensions, with every turn of the coil anchored in place for good.

Another machine of Western Electric design is used for automatic production of the edge wound voice coils which are used in the 754A and 754B speakers and in the high frequency receivers. The use of flat tape to provide increased gap utilization, in special high efficiency voice coils, was developed by Bell Laboratories and the processes for manufacture of such coils have been pioneered by the Western Electric Company.

Magnetizing of the Alnico permanent magnets is accomplished in another special machine developed by Western Electric. The twelve-inch 728B speakers have a field coil permanently built in for original magnetizing of the permanent magnet; the 755A is fitted into a magnetizing coil built into the machine. In either case, the magnetizing coil is given its pulse of current from a condenser-discharge device, which assures use of the amount of energy required for complete magnetization.

Testing of the speakers as they move down the production line, and after completion of assembly, is careful and exhaustive. Quality control is rigidly maintained by complete testing of a very large sample of production—with the larger speakers, every unit is given the complete testing procedure.

The most important inspection and testing procedures are the following:

Diaphragm Inspection: When the diaphragm, voice coil and magnetic gap are assembled, the diaphragm is inspected for holes or other imperfections, and for the proper application of the edge damping material. The centering of the voice coil in the gap, and the proper relative position of the coil turns with respect to the gap, are carefully measured.

Voice Coil Test: The voice coil is tested for continuity and shorted turns.

Mechanical Inspection of Parts: Careful measurement of parts assures proper fitting on assembly.

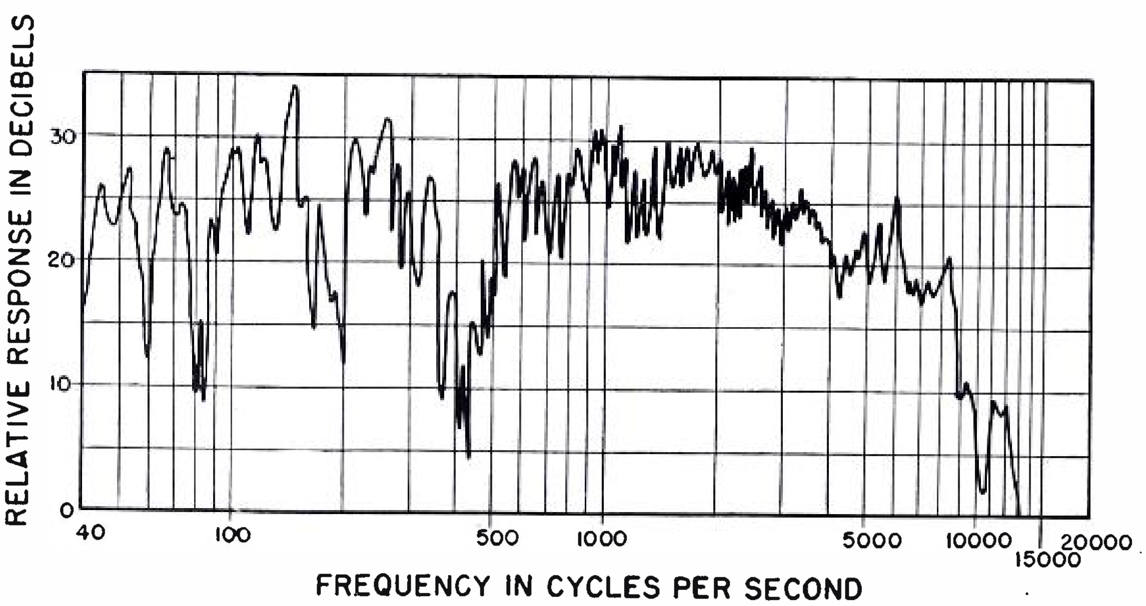


Figure 2 — Response curve of 728B speaker taken in a laboratory "live room" shows effect of reflecting surfaces on characteristic of speaker when sound is a "continuing tone", not like speech or music.

Visual Inspection: With the entire assembly bolted together, it is inspected for finish, mechanical imperfections, bends in the frame, loose terminals, etc.

Noise and Rattle Test: Every completed speaker is given this test, consisting of application of a sweep frequency from an oscillator to determine that the speaker operates properly, that the voice coil moves freely in the center of the gap, and has no obstructions or particles to impede it or loose parts that would cause noise or rattles.

Magnet Flux Test: The proper efficiency of the speakers is assured by a flux test on the permanent magnets, after they have been magnetized. Typical values maintained are the following.

755A—45,000 Maxwells Minimum
728B—90,000 Maxwells Minimum

Response Test: The testing of the completed speaker for frequency response is a most important part of quality control. Comparison of the frequency response of a production model with a previously determined normal curve very quickly shows up any change in manufacturing technique or in the quality or accuracy of any component of the speaker. In Western Electric's Burlington plant, two completely equipped dead rooms have been constructed to carry out the frequency response test. One of them is of conventional construction, lined with flat sound absorbing material about two feet thick. The other room, shown in the photograph on page 13, is a "little brother" of the remarkable new dead room at the Murray Hill Bell Telephone Laboratory, shown on the cover of this issue and described on page 39. It is lined with the wedge-shaped projections of sound absorbing material which provide the necessary coefficient of sound absorption.

The test is made with each speaker mounted in the baffle as shown, and the energy is picked up for measurement by Western Electric's new 640AA Condenser Microphone, which has won widespread acceptance for laboratory and production testing of acoustic devices. The energy applied to the speaker is automatically swept over the spectrum from 20 to 12,000 cycles for the 728B, for instance, and from 28 to 18,000 cycles for the 755A. The response of the speaker is automatically recorded in the form of the usual graph on semi-log paper. The photograph on page 13 shows a typical response curve being removed from the machine after a test. The response-test system was built by Western Electric especially for this purpose.

Thus Western Electric produces a whole line of high quality loudspeakers, each one manufactured and tested with the precision, ingenuity and care that are due a really fine acoustic instrument.

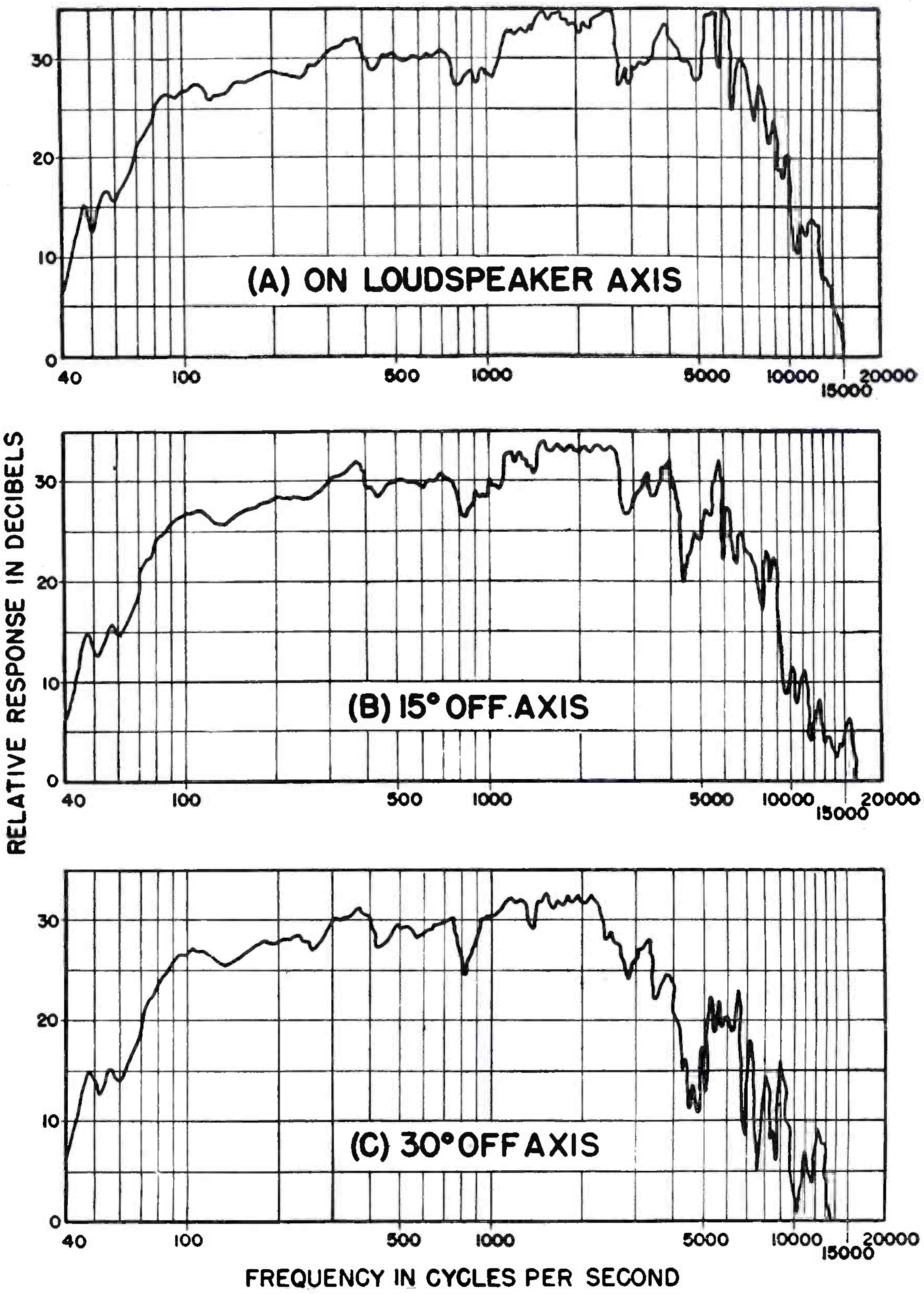


Figure 1 — Typical laboratory response curves used in design of 728B Loudspeaker are the above, which show the frequency characteristic in a "dead room", with microphone at three different positions for pickup.

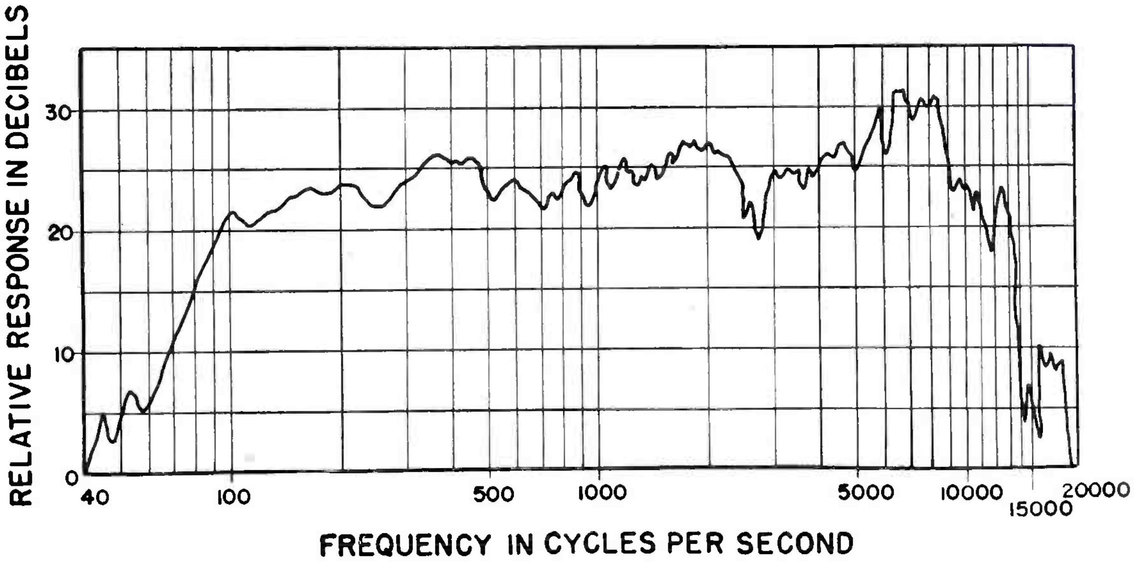


Figure 3 — "Dead room" response of 755A Loudspeaker, measured at a point on the axis of speaker, used to aid the designers in producing the wide angle, wide range response of this eight-inch direct radiator.

Gearing Time to Science

(Continued from page 19)

Over a period of time, the frequency of the crystal changes slightly. The longer the time, the less the subsequent rate of change. After a year, this change is as small as .08 parts in 10^8 per day, or practically negligible. The aging rate of these crystals is quite accurately known, and compensating adjustments are provided in the instrument.

It would take a lot of imagination at the moment to speculate on any requirement for time measurement that would not be satisfied by the D-175730 Primary Frequency Standard. Surely such a need is a long way off, yet should it arise, Science will undoubtedly provide the means, as surely as Huygens applied the pendulum to a clock and made possible the measurement of seconds.

WLAW—Lawrence, Mass.

(Continued from page 17)

000 and the average income per family is $4,250. It ranks high in density of population and no region is more aware of its heritage or its local interests. . . ."

What kind of facilities does this big new station have? Fred Sullivan, WLAW's publicity director and George Hinckley, WLAW's chief engineer, were glad to show us.

WLAW broadcasts from three studios —the main one in Lawrence, one in Boston and one in Lowell, Mass. Of the studio equipment George Hinckley showed us Western Electric cardioid microphones, turntables with 9A Reproducers and 22A remote pickup amplifiers, all in constant use.

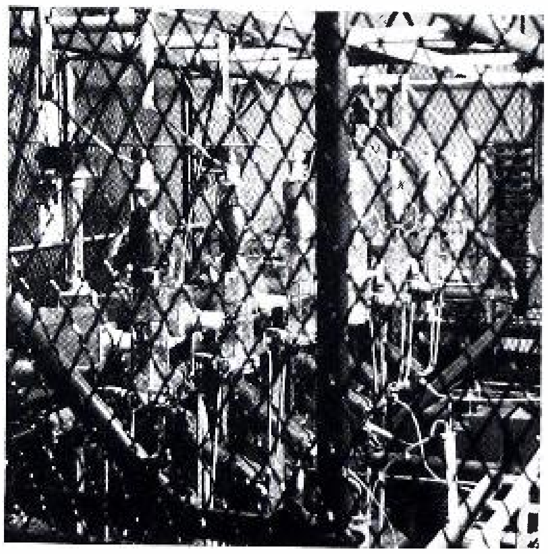
New $350,000 Plant

With Fred Sullivan, we drove out to Burlington, eight airline miles from Boston, 18 miles from Lawrence and three miles from historic Lexington, to view the handsome new transmitter building, the new Western Electric 50 kw AM transmitter and the antennas. This $350,000 plant with its three 440-foot tower quarterwave directional antenna array beaming the station's programs north toward Canada and south toward the tip of southern New England lies on a 100-acre stretch of farm land through which runs a small brook. The whole layout is a sight to gladden the eyes of any engineer.

The antenna towers march north, spaced 623 feet apart, the farthest tower more than 1800 feet from the transmitter building. More than 140,000 feet of ½-inch copper strip were required in the ground system.

The building itself was designed by architect Rene Brugnoni in modern style with an impressive facade of glass blocks between columns of white limestone. This facade is set off against the dark-red brick of the structure. Passing through the vestibule, you come to the central area containing the impressive, new 50-kw transmitter, control console and the 5 kw for stand-by service. Line branching and phasing equipment with a Western Electric 2A Phase Monitor is at the right of the control desk, and adjoining it the main speech input equipment including a Western Electric 1126 Program Amplifier. There is a duplicate system to protect the operation of the station at all times. Fluorescent lighting behind the equipment gives the engineer plenty of light for servicing, and there is indirect lighting from cove troughs. The exterior of the facade is illuminated at night by lights behind the glass blocks at the entrance.

The transmitter building is spacious and well planned. Chief Engineer George Hinckley showed us the living quarters



Row of seven mercury vapor rectifier tubes at WLAW.

for engineers with living room, an adjoining kitchen—with sink, refrigerator, electric stove—and shower bath. In the basement, the transmitter vault houses three high voltage plate transformers, high voltage regulator and small bias regulator; the pump room houses two water pumps and two storage tanks; there is a high voltage porcelain tube room; a small room where nitrogen gas manifolds are located; a large room housing 200-gallon water tanks from the artesian well and two other areas for the storage of maintenance and surplus equipment. A three-car garage completes the structure and the whole building is fully air conditioned for summer.

Outside, on the neatly landscaped grounds, evergreens have been planted along the lawn borders running from a rustic stone wall to the building. George Hinckley pointed out a number of interesting features of the building and its equipment. There is an auxiliary lighting system operating on batteries which provides ample lighting in case of power failure. In such an event, this lighting system is specially placed to guide personnel to the generator room to switch on emergency circuits. In the construction of the building, a 310-foot artesian well was sunk for drinking water, technical and air conditioning purposes. A mobile trailer with full equipment for emergency remote broadcasts with its own 750-watt gasoline engine-driven a-c generator rounds out the transmitter facilities.

The Men Who Run It

Most of the men who run WLAW have been together as a team for a long time. They are old hands in the newspaper business and old hands in their community. The late Alexander H. Rogers brought most of them with him from his newspaper organization.

General Manager Morrill's interest in radio goes back to World War 1 when he was an officer in the radio, communications and intelligence service overseas. This interest has stayed with him through a business and financial career.

It was Harold Morrill who persuaded the late Mr. Rogers that radio was a good investment. He was thus the natural choice to supervise the construction of the station in 1937 and to guide its affairs as it increased in power. He became the station's general manager in 1946, when Irving Rogers, its original general manager, decided to devote his major efforts to his newspaper interests.

National Sales Manager of WLAW is Matthew J. Noonan. With 25 years' experience in advertising and merchandising, Matt Noonan was national advertising manager of the *Boston Post* for 13 years and sales manager of the advertising firm of John C. Donnelly & Sons for two years.

Director of Public Relations is Fred A. Sullivan. Fred is another old hand in the team, having started his career back in 1914 with the Rogers interests as a reporter, feature writer, promotion director and associate city editor for the *Evening Tribune*. In 1946, he took over the promotion and public relations section of WLAW.

With a wide background in radio broadcasting, James T. Mahoney is WLAW's program director. Jim started his career as an Artists' Bureau representative. In 1935, he went into the recording field as a transcription manager and from there two years later became a network production director. In 1941, he was a civilian property and supply officer, AAF, and in

1943 went into the OWI, overseas. He was production manager for a Baltimore station until 1946 when he came to WLAW.

Local Sales Manager of WLAW is the third old hand with the Rogers organization —David M. Kimel. Dave Kimel started back in 1915 as a newspaper reporter for the *Lawrence Daily Eagle* and has been with the *Eagle-Tribune* group ever since. He became manager of classified advertising of the *Eagle-Tribune* firm and in 1937 was brought in as sales manager of WLAW. As the station's Boston representative, he has Miss Eleanor Kane Kirby, one of the brightest lights of the WLAW sales staff. She had a theatrical background, went into the sales end of the radio industry in 1935 and joined WLAW two years ago.

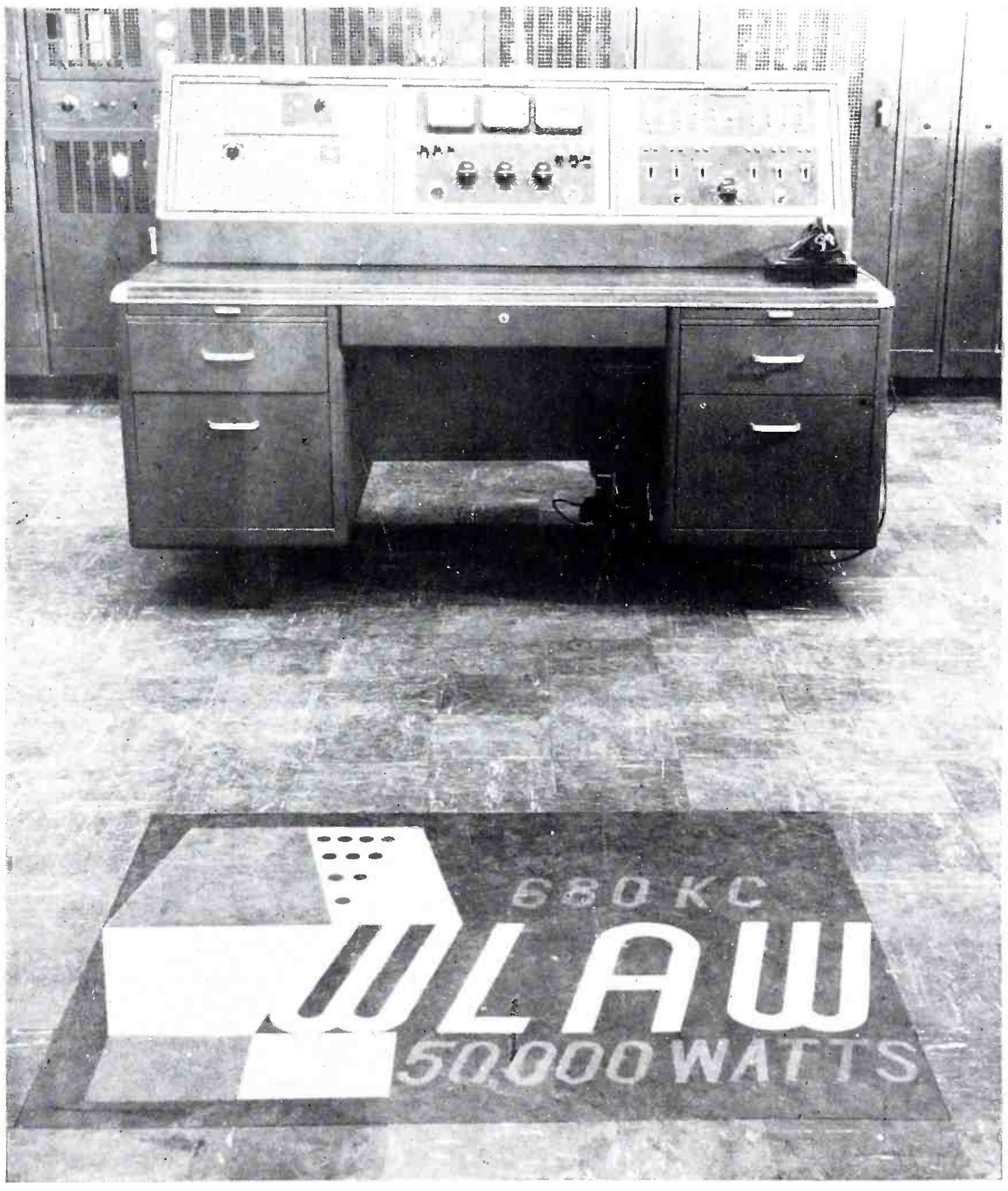
A Fine Technical Staff

On the technical side, the station boasts a first-rate crew under the able direction of Chief Engineer George A. Hinckley. George himself has been a ham since 1920, with call letters having his first two initials W1GA. It was George Hinckley who supervised the technical facilities in the station's climb to 5 kw in 1940 and who was chiefly responsible for the technical excellence of the station as it jumps to top power.

Assisting him is a staff of fourteen engineers: Robert C. Bingham, Kenneth F. Smith, Perley W. Tribou, Alden Doughty, Frank W. Lee, James H. Riley, Ernest A. Pfeiffer, Donald J. Lee, Maurice Polayses, George P. Jowdy, Morton B. Rowe, Edward J. Riemitus, Thomas Matarazzo and Edward Pfund. Seven of these men are also hams, including Ken Smith with call letters W1MRQ; Ernest Pfeiffer W1JJE; Donald Lee W1LYN; George Jowdy W1KBO; Morton Rowe W1JRN; Ed Riemitus W1OMG and Ed Pfund W1MGY.

When we asked Mr. Rogers about his future plans for the station, he told us: "We're going to try to make this station a real servant of the people of New England. We're going to give them the best programs we can over the best technical equipment we can get. We are going to use every available facility too. We have a construction permit for a 17 kw FM with a 625 foot antenna to be located on our West Andover site. And we even have some plans, though they have not reached the blueprint stage, for television. We have been given a great opportunity with our new vastly increased power to serve this community, and we are going to use all the experience, talent and resources we can muster to prove equal to our good fortune."

WLAW goes on the air at 50 kw! Flipping the final switch, Alexander H. Rogers, 2nd, namesake of station's founder, puts station at full capacity. Observing him are members of the Rogers family, l. to r. Mrs. Irving E. Rogers, Allan B. Rogers, Mrs. Alexander H. Rogers, Irving E. Rogers, Jr. and Irving E. Rogers.



View of Transmitter Control Desk at WLAW's new 50 kw transmitter. New station facilities in the handsome transmitter building include line branching and phasing equipment with Western Electric 2A Phase Monitor at right of control desk and speech input equipment including a Western Electric 1126 Program Amplifier.

E. M. Hall

E. L. Younker

A. W. Colledge

H. W. Augustadt

Contributors to This Issue

E. M. HALL, author of *Sound Reproduction Comes of Age,* (page 3) is manager of Sound Systems and Communications of Western Electric's Radio Division. He received his M.E. degree from Cornell University in 1916. After serving in World War I as a Naval air pilot, he joined Western Electric in 1919 as an engineer at West Street, New York. In 1922 he worked on the first large public address systems designed by Bell Laboratories for the Harding inauguration in Washington and the Telephone Pioneer Convention in St. Louis. He later worked on some of the first broadcast installations made by Western Electric. In 1923 he was a price engineer in the Contract Sales Department and, in 1928, he transferred to Electrical Research Products, Inc. He later became Assistant Export Manager and Manager of the Western Electric Company of Cuba with headquarters in New York. In 1936, he was transferred to London as commercial director of Western Electric Company, Limited. In 1940, he served as Washington representative for Western Electric's Specialty Products Division. He became assistant to F. R. Lack, then Manager of Radio Sales Division, in 1942, and served thereafter as staff manager in charge f personnel and government contracts and as manager of sound systems an l nobile radio.

E. L. YOUNK uthor of *An RF Wattmeter and In ance Monitor for FM Broadcasting,* ge 25) graduated from Miami Univer (Ohio) in 1940 and received his A.M degree in Physics from the University Illinois in 1942. From 1942 to 1945 l as a staff member of the Massachusetts I itute of Technology Radiation Laborat y. At the end of 1945, he joined the Specialty Products Department of Bell Telephone Laboratories, where he has been working on broadcast antenna and transmission line problems. He was co-author with J. F. Morrison of a paper describing the Power and Impedance Monitor presented before the 1947 Winter Convention of the *IRE*.

A. W. COLLEDGE, author of *Gearing Time to Science,* (page 18) is sales engineer for Sound Equipment and Industrial Products in Western Electric's Radio Division. He received his B.S. degree in Electrical Engineering from Cooper Union in 1922 and his E.E. degree in 1930. Mr. Colledge joined the Electrical Research Products, Inc., known as ERPI, in 1929. At ERPI he worked on sound motion picture reproduction and recording and he later became Director of Engineering Applications in the acoustic consulting and instrument field. In 1941, he was called to active duty by the Navy to organize the Physics Research Section in the Bureau of Ships, where he did extensive work in secret Naval research and experimentation in sonar. He left the Navy in 1945 with the rank of Captain. Mr. Colledge was awarded the Legion of Merit for his work in the quieting of submarines. He is a Fellow of the Acoustical Society of America.

H. W. AUGUSTADT, author of *A New Line of Amplifiers,* (page 22) graduated from the University of North Dakota in 1928 with a B.S.E.E. degree. He joined Bell Laboratories that year and went to work on the design, development and construction of filters, equalizers and phase correctors for use in carrier telephone and telegraph systems. A part of his work was on electromechanical filters for use in high gain heterodyne detectors. In 1933, he received his M.A. in Physics from Columbia University. The next phase of his work was concerned with design of amplifier equipment for use in motion picture theatres, radio broadcasting studios and public address systems. Among his contributions may be noted early experiments with negative feedback in commercial amplifier designs, application of voice operated circuits to program regulating devices for radio broadcasting. During the war, he worked on radar fire control equipment for the Navy. He is at present engaged in development in the sound distribution and recording systems field.

Nation's Tallest Antenna Tower

In the article "Clover-Leaf in the Clouds" in the March 1947 issue of the *Oscillator*, a description of the new 959-foot antenna tower structure at WKY, Oklahoma City—the Nation's tallest—was published. Inadvertently, the article omitted the important contributions to this unique tower of Glenn D. Gillett, consulting radio engineer of Washington, D. C.

Mr. Gillett was designer of this 915-foot AM Franklin-type antenna, and it was he and his associates who prepared for WKY comparative studies on the coverage that could be obtained from the old WKY site and the present site, both in the Oklahoma City area, using both the half wave antenna and the Franklin. On the basis of these studies, WKY moved its station to the new site. Mr. Gillett was responsible for the provision in the design of the AM tower for an additional bending moment of 31,000 ft.-lbs., thus making possible the later erection of the FM antenna; the means for tuning the tower at mid-point and base; the means for carrying the $6\frac{1}{8}$-inch concentric line with lighting circuits; and five monitoring loop circuits by the main and mid-point insulators.

During the war, H. J. (Jack) Lovell, chief engineer of WKY, following the detailed instructions provided by Gillett on how to adjust the Franklin and the directive, made, with Dixie McKey, all necessary adjustments and measurements.

KSFO Did Not Lose A Minute

Receiving KSFO silver pocket awards from Engineer in Charge Alfred Towne for not losing one minute of commercial time last year are, left to right, Tom Lewis, Roald Dedricksen, Ray Holtz, Charles Mentz and Nathaniel Faithorne. This 5 kw San Francisco station has a Western Electric 355E1 transmitter.

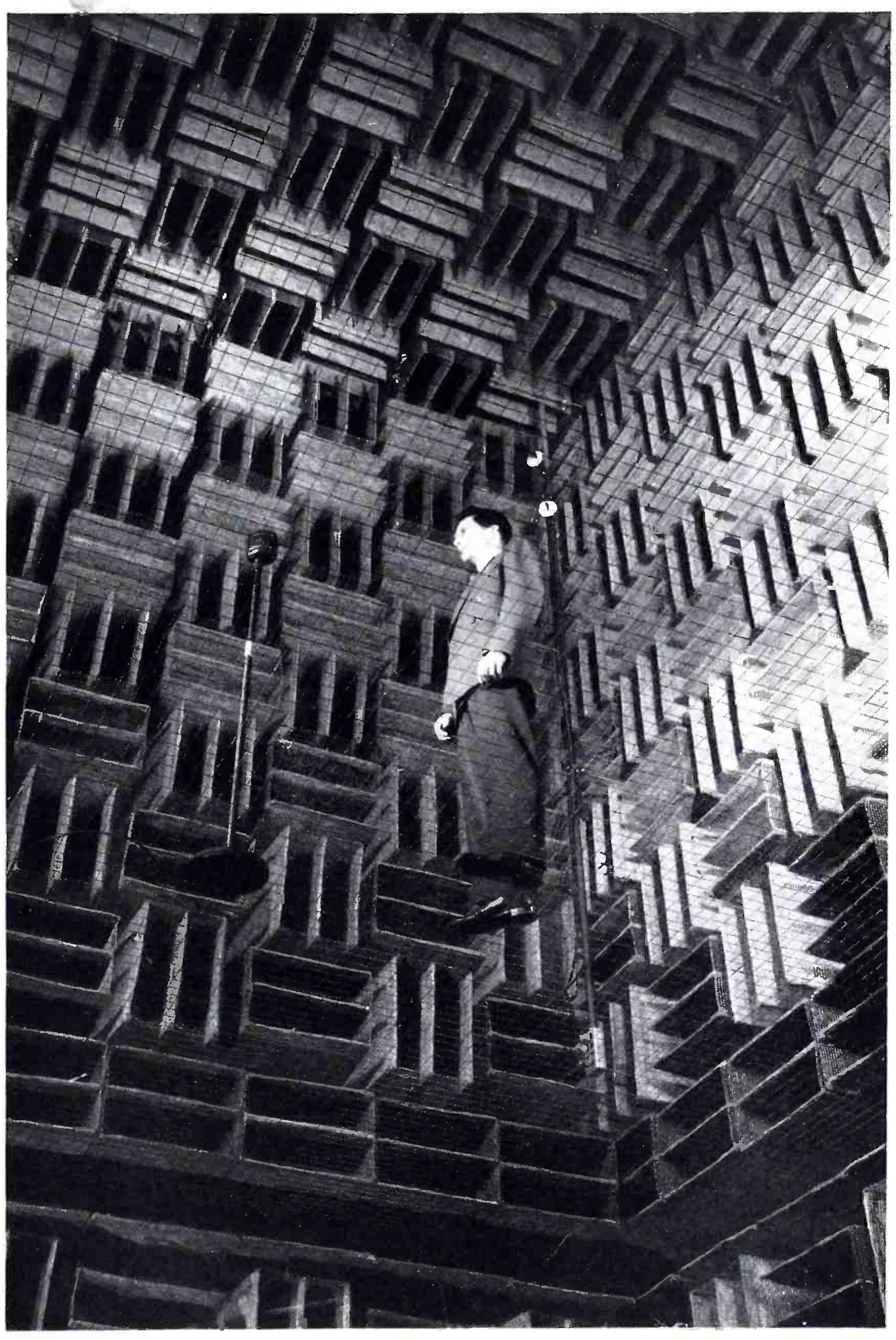
New "Free Field" Acoustic Test Room at Bell Laboratories

It's a strange world that Bell Telephone engineers have created in the new non-reverberant chamber at Murray Hill, one of the two or three "deadest" rooms in the world, which is shown on the cover of this issue. This acoustic test room incorporates many new and ingenious design ideas to make sure that Bell Telephone Laboratories research and development on acoustic devices, such as the 757A Loudspeaker shown in the cover picture, can be carried on with the absolute freedom from extraneous noise and reflected sound demanded in many phases of modern acoustic laboratory work.

The small amount of extraneous noise at the quiet Murray Hill country location is kept away from experiments in the room by the two-foot thick masonry structure and the mechanical isolation of the room from all other building structures. The dust-free air, with controlled temperature and humidity, is brought into the room and exhausted through an elaborate system of acoustic filters and lined ducts.

Reflections have been almost perfectly eliminated from the interior by the five-foot long wedge-shaped cages of wire mesh filled with glass wool, which are applied to the walls, ceiling and floor in a close array with the points outward. Every surface in the room is, in effect, five feet deep in sound absorbing material. This forms a treatment which is designed to absorb, at the wall, 99.98% of all the incident sound energy in the audible range. The effect of the two hundredths of one per cent which is reflected is minimized by making the room large enough (28 ft. x 28 ft. x 30 ft. inside treatment) so that all walls are well removed from the test area.

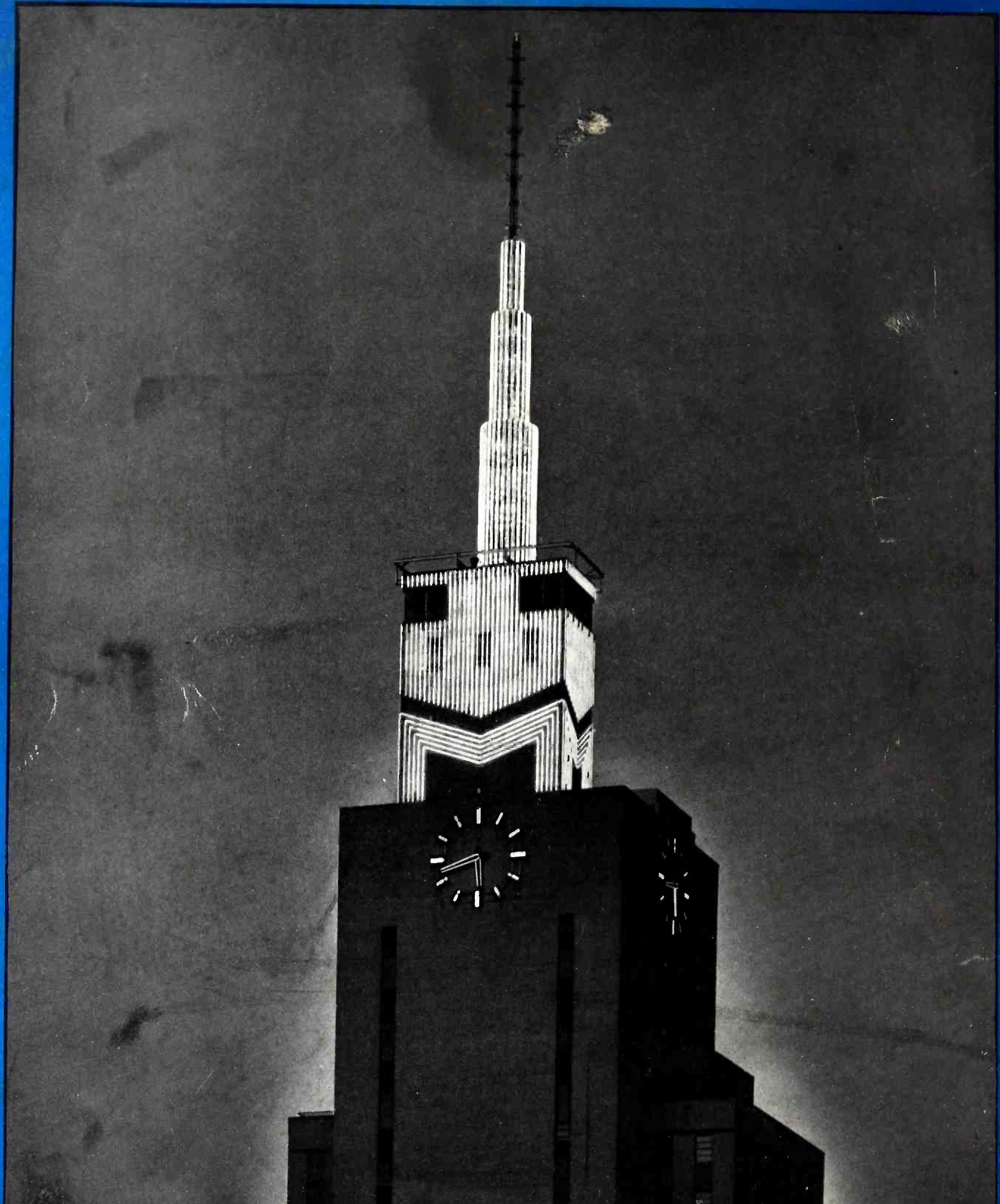
The acoustically transparent floor, which furnishes the up-in-the-air effect for the cover picture and for the accompanying photograph, is slightly below the geometric center of the room and is made of stranded steel cable, 1/12.5 inch in diameter, spaced two inches apart and stretched across the room in two directions. Coil springs, anchored to the wall, maintain a tension of 300 pounds on each cable. The entire floor can support a distributed load of 8000 pounds with a good safety factor. A 150-pound man at the center of the floor depresses the cables about ¾ inch below the unloaded position. This floor, in contrast to the arrangements used in earlier test rooms, permits working over the entire cross section of the room without offering any surfaces to reflect sound in the audible range.



Standing on the "floor" of the new acoustic test room at Murray Hill looks like a circus act at first glance, but the steel cables actually form a convenient, sound-transparent working platform for testing.

Illumination is furnished by eight reflector lamps, which are easily removed from the room if the test conditions are affected by the one square foot of reflecting surface which they offer. Steel hangers are provided, projecting through the wedges on the ceiling, to which equipment can be fastened if it is desired to eliminate any slight movement of the floor from the equipment under test.

Thus every device has been used to make this the perfect "idealized" environment for convenient study of the action of electro-acoustic instruments.



Clover-Leaf Antenna, KERA, Dallas