PICK-UPS

JULY · 1936

In This Issue

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Western Electric

— PICK-UPS —

BEING A PERIODICAL DEVOTED TO DEVELOPMENT IN SOUND TRANSMISSION. PUBLISHED BY THE

Western Electric Company

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JULY, 1936

The NAB Convention

Critics of American business often ridicule and look with scorn at the American business man's habit and practice of attending conventions. A motion picture was made and successfully exhibited which laughed uproariously at the whole idea of conventions. Perhaps the very men who go to conventions, when they get home and figure the cost of attending them, often wonder if they are worth the time and expense. We believe they are.

But seriously, the convention is the place where new ideas are born, where old ideas and bad prejudices are discarded. Perhaps a mere suggestion made on the convention floor will sink into the minds of one or more men. That idea in the months to come is pondered in the minds of those men, and eventually bears fruit in action. New policies, new developments result which change and better the course of an entire industry.

Men see new equipment and learn of new ways of doing old things at conventions. They hear and see what the other man is thinking and doing. They become dissatisfied with their own meagre accomplishments, receive inspiration to work harder, accomplish more. Such things in themselves are justification enough for any convention.

At this, the fourteenth annual convention of the National Association of Broadcasters, members will see all manner of new developments. They will hear ideas and policies discussed which will affect the whole future course of American broadcasting. The past year has seen vast changes in the broadcast scene. Equipment has been developed and is ready for marketing which will advance tremendously the art of radio broadcasting. These developments will be on display. They alone will make the convention worthwhile to the visitor.

It seems strange that the ranking association of an industry which affects the lives of so vast an audience, which employs so many thousands of people, which stands so high in the list of great American industries should be having this year only its fourteenth annual convention. This fact alone is evidence enough of the tremendous growth, the wonderful appeal of radio. Also, it is a testimony to the vision and the capabilities of the men in radio today.

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This Issue

Radio
Must Learn How To Teach

SAYS EDWIN W. CRAIG

An interview with the
Director of Station WSM, Nashville, Tenn.

By

WILL WHITMORE

Edwin Wilson Craig

Back in 1922 a young insurance man became interested in that new thing called radio. While twisting dials and adjusting the cat whisker, he often wondered if radio could not be used to sell insurance. That idea, by 1925, had taken concrete form and Station WSM went on the air in Nashville to sell insurance for the National Life and Accident Insurance Company.

Today, the young man, Edwin Wilson Craig, is vice president of the insurance company, director of the station which grew from its original 1,000 watts to its present 50,000 watt power, and is one of the leading figures in broadcasting in the U. S. A. He is a member of the board of the National Association of Broadcasters and chairman of the newly formed group organized in the interests of clear channel stations.

After graduating from Vanderbilt University in 1914, Craig went into the insurance business, and served in almost every capacity in that field of human risks. Today he has charge of his company's 3,000 agents in 21 states.

Down in Nashville, we planned a talk with Edwin Craig about Edwin Craig. After leaving him and reviewing our conversation there dawned a realization that we had not talked about Craig at all. We had talked about radio the entire time.

That seems typical of the man. Radio occupies much of his working time, and a great deal more of his thoughts. One leaves him with the firm impression that he is far more interested in what he can do for radio than in what radio can do for him. Radio today needs more Edwin Craigs.

"We broadcasters do not know the answers to many of radio's most pressing problems," said Craig. "There are still too many owners who do not know enough about their stations, and broadcasters in general who do not use enough discrimination in program selection."

These statements at first may seem to be an indictment of radio. But are they? The profession of law is almost as old as human society, yet lawyers still argue and fight over codes of ethics. Newspaper publishing is almost as old as the printing press, yet editors and publishers constantly discuss the rights, privileges, and obligations of the press. The profession of radio (and the sooner it is regarded as a profession, the better) is so young that its life can be measured in minutes compared to other professions. Yet, in the few brief moments of its existence, it has accomplished miracles. That is why any criticism of Craig's or of others well versed in the broadcasting industry should be taken as constructive advice rather than denunciation.

In talking with Craig, the similarity of his ideas with those of Leo Fitzpatrick, an interview with whom appeared in an earlier issue of "Pick-Ups," is striking. The two men are close friends. In fact, it was Fitzpatrick who fostered Craig's early interest in radio. Where Fitzpatrick thinks in lightning jumps, Craig thinks slowly, deliberately, though none the less surely. Perhaps it is significant that two men, both leaders in radio, and yet as unlike as nature and environment could make them, should hold such sim-

(*Continued on Page Twenty-eight*)

Doherty Circuit

High Efficiency for the Broadcast Transmitter

New Principle in Linear Power Amplifier Design

By W. H. DOHERTY

Radio Development, Bell Telephone Laboratories

Often one resorts to intricate or cumbersome means to achieve a new result, and later finds that a better and simpler solution was so obvious as to have escaped him. The high-efficiency circuit, recently announced as a feature of Western Electric high power broadcasting equipment, which approximately doubles the efficiency of linear power amplifiers, is a rather striking example of how near at hand the solution to a problem may be if one has the requirements clearly in mind.

Most radio-frequency power amplifiers operate at a plate efficiency of between 25 and 33 per cent. Many an engineer has reflected with chagrin on the necessity for supplying to the tubes a plate power of over three times their carrier output, only to have most of this power dissipated at the anodes of the tubes. The situation has naturally become more acute as the power outputs employed in broadcasting have increased. At carrier outputs of 50 kilowatts and higher, power consumption and the water cooling problem assume major importance.

It has been generally believed that efficiencies higher than 33 per cent were to be attained only by modulating at the final stage. The new system, however, permits low-level modulation to be employed in the usual manner and the succeeding stages are purely amplifiers. The efficiency of the final amplifier stage is 60 per cent or more, so that its power consumption is approximately cut in half and the plate dissipation reduced to one-third that of the conventional linear amplifier.

Efficiency in power amplifiers is directly proportional to the ratio of alternating plate voltage to dc plate voltage. The low average efficiency at which the conventional linear amplifier must operate is due to the fact that in order to permit the amplifier to respond to the positive peaks of a completely modulated wave, rarely though they may occur, the alternating plate voltage, and hence the efficiency, with unmodulated carrier must not be more than half of the maximum possible value.

Now the important point to observe is that the requirement of large plate voltage swing for high efficiency imposes no restriction whatever on the plate current. If, then, one could vary the load impedance at audio frequency during the modulation cycle so as to permit the tubes to deliver a varying current to the load, but at a large and constant radio-frequency plate voltage, then the efficiency would be high both with modulation applied and with unmodulated carrier. A novel means for obtaining automatically and instantaneously a variation in load impedance during the modulation cycle is an essential feature of the new scheme.

A second possibility that occurs to one in seeking a solution to the efficiency problem, is the possibility of obtaining the smaller instantaneous outputs—in particular, the carrier output—from a reduced number of tubes at high efficiency, and then bringing into action additional tubes to furnish the added power required on the positive swings of modulation. This possibility has not previously been utilized because it happens that in the conventional parallel or push-pull circuit the coming into action of additional tubes would cause an effective increase in the impedance into which the original tubes worked, with a consequent reduction in their possible output, and no increase at all in the total output of the amplifier.

By an extremely simple modification of the circuit, however, exactly the opposite effect is obtained, i.e., the load impedance to the original tubes is reduced as the additional tubes come into action. At once both of the above possibilities for high-efficiency operation are realized—a varying load distribution among the tubes and a varying circuit impedance over the modulation cycle, one of these desired effects being the immediate result of the other.

The circuit which provides this required impedance variation evolves directly from the conventional amplifier circuit shown symbolically in Figure 1, where two tubes, each designed to work into an impedance of 1000 ohms, are shown connected in parallel to a 500 ohm load. As long as the load is shared equally by the tubes, each works

(*Continued on Page Twenty-six*)

The illustrations on the opposite page are reproductions of free-hand pencil drawings made by Mr. Doherty to explain the theory and operation of his circuit. →

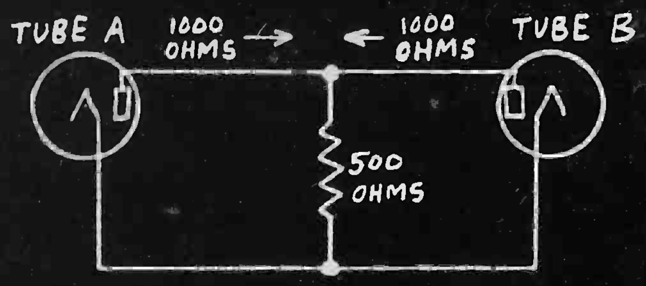


FIGURE 1

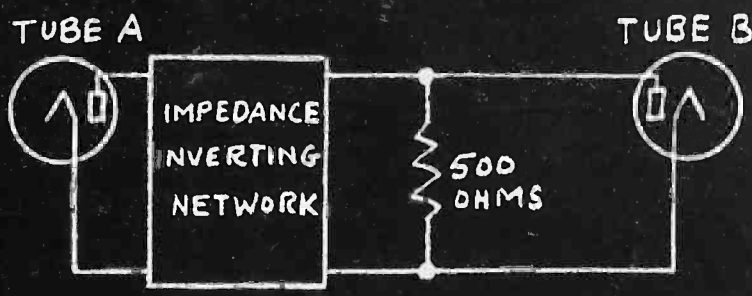


FIGURE 2

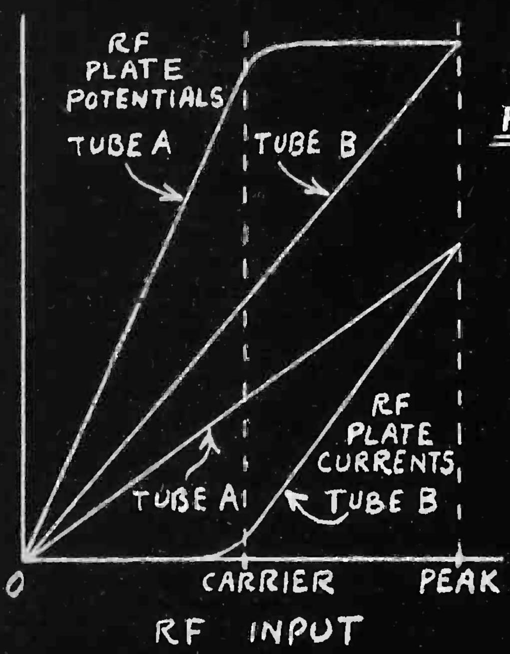
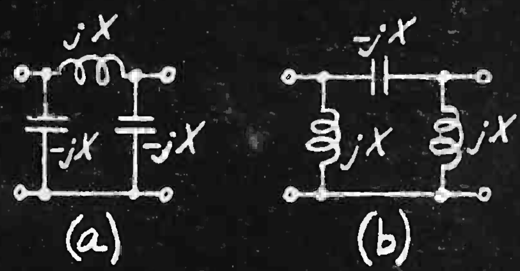


FIGURE 3

FIGURE 4



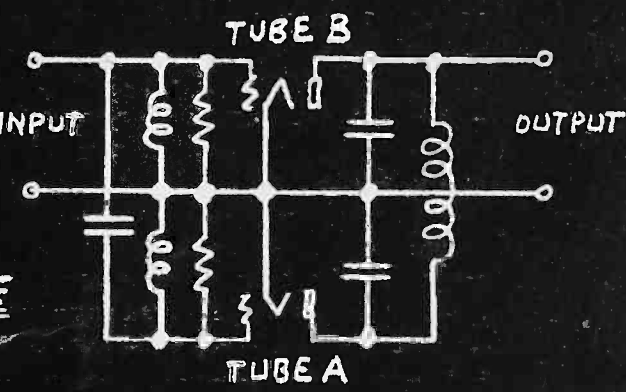
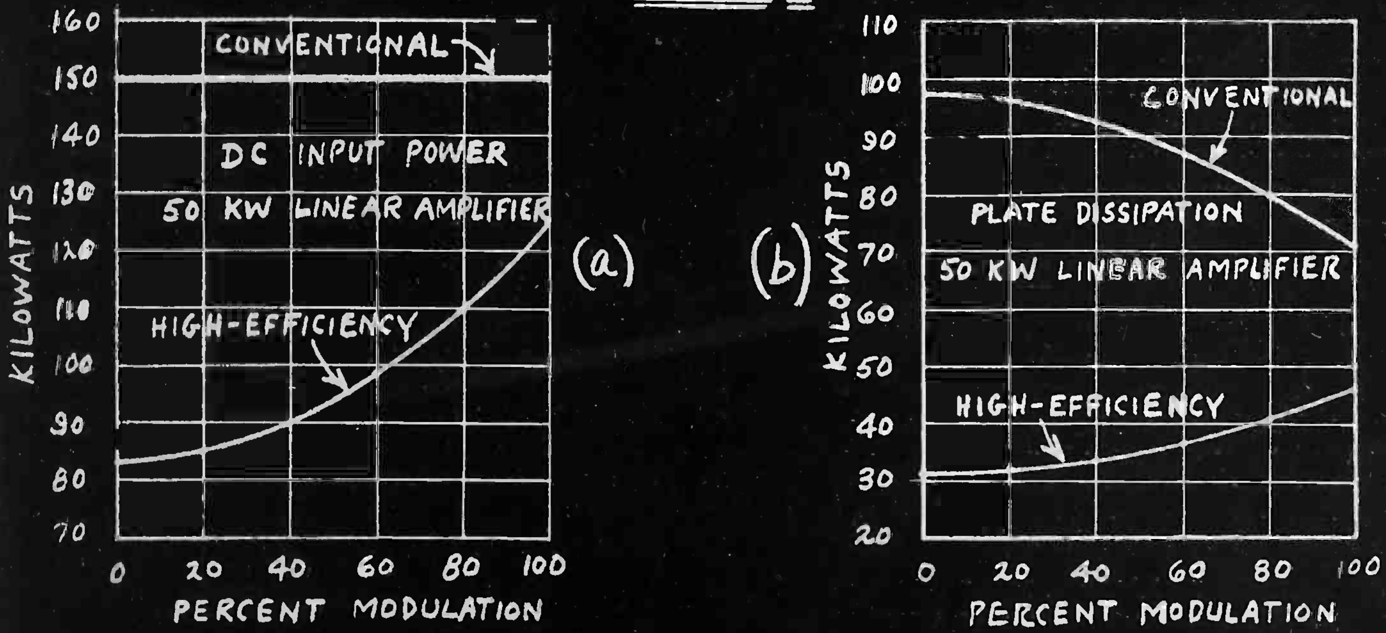
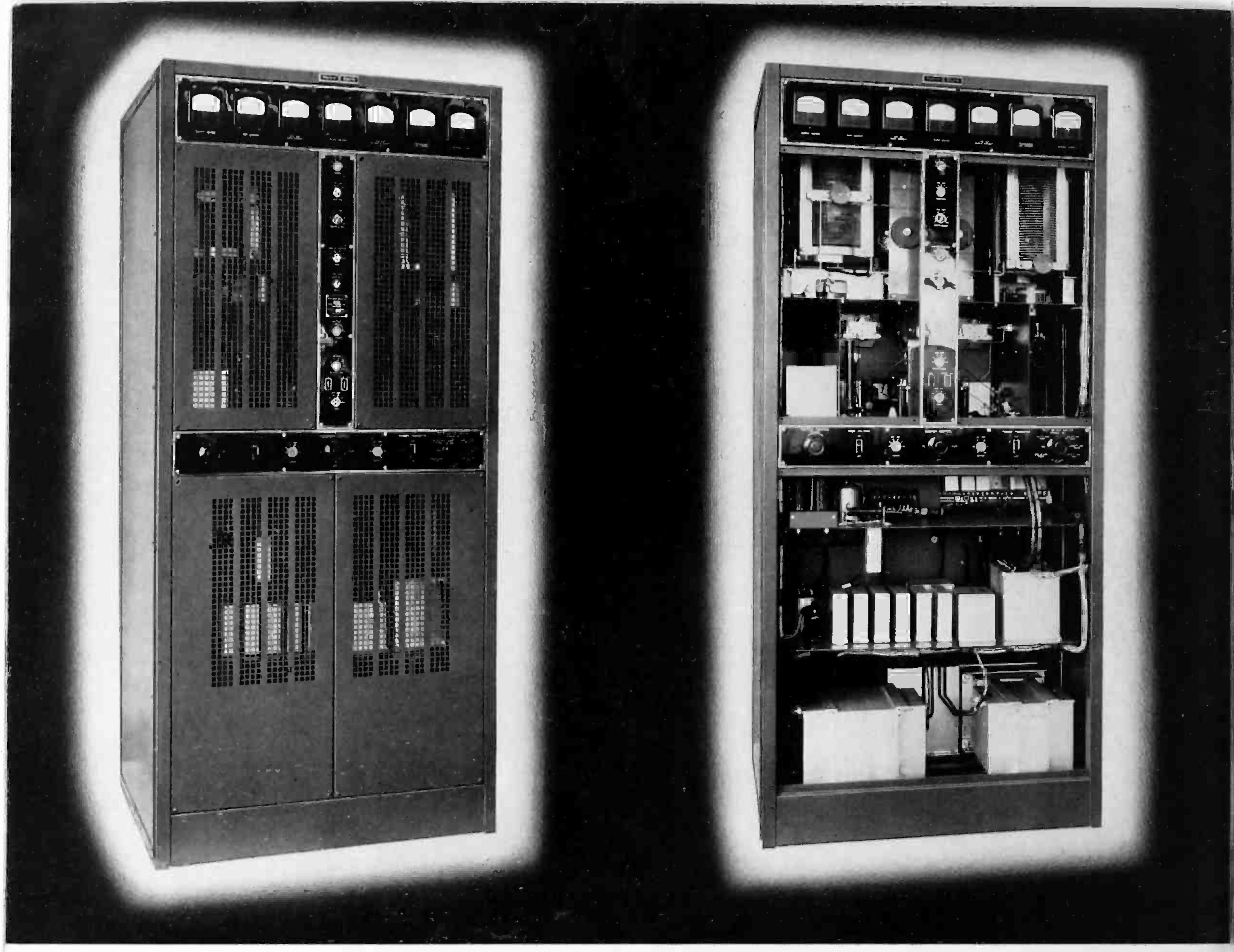


FIGURE 5

FIGURE 6





New 100-250 Watt Transmitter Uses Small Tubes, Less Current

By R. E. CORAM

Radio Development, Bell Telephone Laboratories

The 23 A Radio Transmitter is an inexpensive 100-250 watt equipment built to give the same high quality of radiated signal now characteristic of the newer high powered stations. In addition to this high fidelity performance, which is discussed more in detail below, one of its outstanding features is an economy of operation not usually found in transmitters of this power. Through the achievement of a high overall efficiency accompanied by the low cost of the smaller types of vacuum tubes which are used throughout, the cost of operation has been reduced to a remarkably low value. The transmitter has been designed specifically for the 100-250 watt field, although it is suitable for association with the 90 A (1,000 watt) Amplifier where an increase in power under existing regulations is assigned to the station at some future time.

The economy of operation and high fidelity performance at outputs of either 100 watts, 250 watts, or 250 watts daytime and 100 watts nighttime is the result of employing a simple and straightforward circuit arrangement. It consists of an oscillator and four stages of radio frequency amplification with modulation taking place in the second stage. A two-stage audio amplifier provides the necessary speech power and a single full wave rectifier supplies all of the necessary bias, plate, and screen voltages. Low level modulation, which has been featured in Western Electric transmitters for more than a decade, is continued in this new equipment.

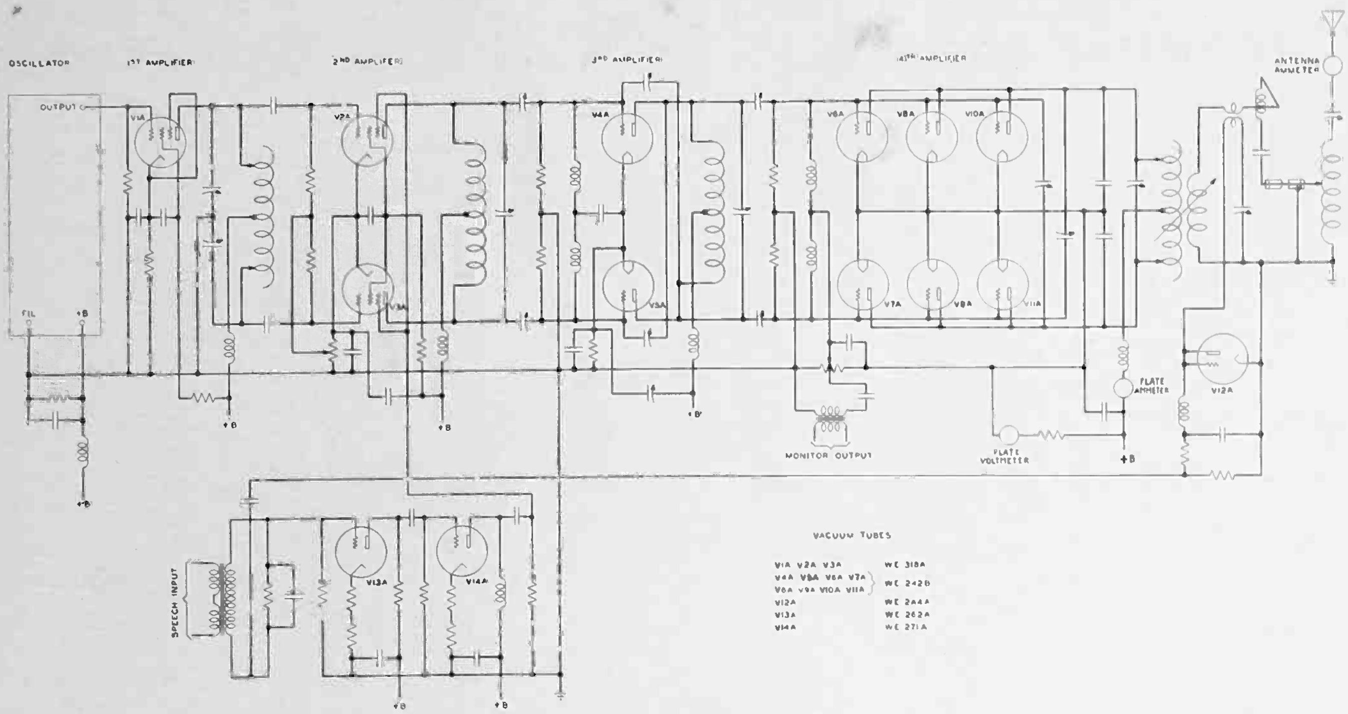


Fig. 1 — Schematic of 100-250 Watt Transmitter

A simplified schematic of the transmitter circuit is shown in Fig. 1. The 702 A Oscillator employed is the latest Western Electric product. It uses the new low temperature coefficient crystals developed by Bell Telephone Laboratories which have a frequency variation with temperature of only a few parts per million per degree Centigrade. The use of this much improved crystal has permitted replacement of the usual delicate mercury thermostat with a sturdy thermal relay which regulates the temperature in the crystal oven to a fraction of a degree.

The use of this type of heat control obviates the necessity of the grid controlled rectifier tube which was formerly supplied to take care of the inability of a mercury thermostat to handle currents of more than a few milliamperes. Provision is made for a spare oscillator which is kept at operating temperature so that in the remote event of oscillator failure, it can be inserted in the slide from which the regular oscillator is removed. Lamps are provided on both oscillators, which are lighted when the operating temperature is correct. Either too high or too low an oven temperature will extinguish the lamp associated with the particular oscillator.

Modulation takes place in the second R.F. stage which uses two Western Electric No. 318 A Vacuum Tubes. These have a second grid which is called the suppressor but which is probably better described as a second control grid, as the amount of bias needed on it is of the same order of magnitude as on the control grid. Radio frequency is supplied to the control grids as in any push-pull amplifier, and the audio frequency voltage from the audio amplifier is supplied to the suppressor grids in parallel. This method of modulation is a simplification of the grid bias method in that it provides isolation between the radio frequency and the audio frequency inputs to the modulating stage.

There are a number of very interesting features in the two linear amplifier stages which follow the modulation stage that will be clear from inspecting the circuit diagram. The series condensers between the stages provide a very accurate control of the impedance into which the tubes ahead of them operate. This feature will be appreciated by the technically informed as a distinct improvement over earlier devices that serve the same purpose.

For 100 watt service, four tubes are used in the final radio frequency stage. Six tubes are used for 250 watts output and for the double power assignment of 100 watts night-time and 250 watts daytime. The change-over from day to night power is made without program interruption by the operation of a single switch.

The output of the transmitter is connected through a concentric transmission line to an antenna coupling unit shown in the second photograph. This may be mounted either in the transmitter room at the point where the antenna lead-in wire enters or at the antenna tower in case the antenna structure is remote from the transmitter building. A meter circuit is provided on the transmitter which is energized from a thermocouple in the antenna coupling unit so that it is not necessary to actually visit the antenna coupling house in order to log the antenna current. Where this coupling unit is exposed to the weather, a weather-proof box is available for its protection.

Another very important feature incorporated in this equipment is the use of stabilized feedback. There is no need to dwell upon the effectiveness

(*Continued on Page Twenty-four*)

Super-Stability for Radio Carriers

Western Electric's New 702 A Oscillator Uses Low Temperature Coefficient AT Cut Crystal, Controls Frequencies to within 10 Cycles

By O. M. HOVGAARD

Radio Development, Bell Telephone Laboratories

One of the most vital elements in a radio transmitter is its source of carrier frequency. Probably it is needless to say that in the absence of an oscillator all other components of a transmitter are rendered idle while if the oscillator becomes erratic in its behavior, the transmitted signal may lose its effectiveness. Considerable effort is justified, therefore, to secure the utmost possible reliability of performance in the master oscillator.

Since its application to radio transmitters by the Western Electric Company a decade ago, the quartz controlled master oscillator has had no peer. Nevertheless, Bell System engineers have continuously sought to improve its operation, and their efforts have recently resulted in a major improvement in this art.

The development of low temperature coefficient quartz plates by Bell Telephone Laboratories and their commercial introduction during the past few years has brought about a complete change in the accepted standards for the generation and maintenance of carrier frequency. Today, low temperature coefficient quartz plates enable the broadcast industry to attain a degree of frequency stability far better than called for by the regulatory requirements and to do so with a margin of safety commensurate with good engineering practice. The performance of the new quartz plate is such an improvement over that of its predecessors that it has been referred to frequently as a "zero temperature coefficient plate," a designation which only can be justified by relative performance.

Experience shows that ambient temperatures anywhere from 0° C. to 60° C. may be encountered in broadcasting installations. After a quartz plate has been adjusted to be exactly on frequency at 30° C., it may be subjected to a temperature variation of ± 30° C. If the nominal frequency of such a plate is 1500 kilocycles and assuming that a safety factor of 2 to 1 is allowed in meeting a specified tolerance and that but ⅔ of the permissible deviation can be allocated to temperature variations, it is found that in meeting a 50 cycle tolerance there is left about 16 cycles for temperature changes.

Under the above conditions, if there were no temperature control, the change in frequency per degree Centigrade—the temperature coefficient—could not exceed about ½ cycle in 1500 kilocycles or ⅓ cycle in a million. Theoretically, it is possible to obtain plates with such characteristics but very rigorous requirements are imposed on the manufacturing processes involved and the product becomes correspondingly expensive. As a practical matter, therefore, the combination of plates having a temperature coefficient of 2 or 3 cycles in a million per degree Centigrade and a relatively simple, rugged and inexpensive temperature control system to maintain the temperature of the quartz within reasonable limits appears to be the best solution.

In the recently designed Western Electric 702 A Oscillator the low temperature coefficient AT cut quartz plate is combined with an exceedingly simple temperature control mechanism to provide a stability of generated frequency well within 10 cycles of the nominal value. This oscillator is employed in broadcasting and police radio transmitters operating in the 550 kilocycle to 3,000 kilocycle band. Except for the power supply required for the oscillator tube and the oven heater, this oscillator is a self-contained unit, fully automatic in its operation.

Its construction is in the form of a chassis, about 4″ x 9″ x 2″, on the top of which are mounted the oven and a Western Electric 247A Vacuum Tube. All other elements of the circuit are contained within the chassis which serves as a shield as well as a mounting frame. Connection to supply voltages, indicating meters, alarm circuit, and the radio-frequency load are all made through spring clip terminals contained in a strip at one end of the chassis.

When an oscillator is inserted into a transmitter, the bottom of the chassis engages two tracks and the terminal strip automatically makes all contacts to a similar strip which is a part of the transmitter. The spring pressure of the contact strip is used to force the oscillator chassis against detents located at the outer end of the tracks, thereby assuring good contact pressure at all times.

The circuit used in the 702 A Oscillator is composed entirely of resistors and capacitors. These elements can be manufactured to a high order of precision and possess good stability with respect to time, temperature, and moisture. A characteristic of

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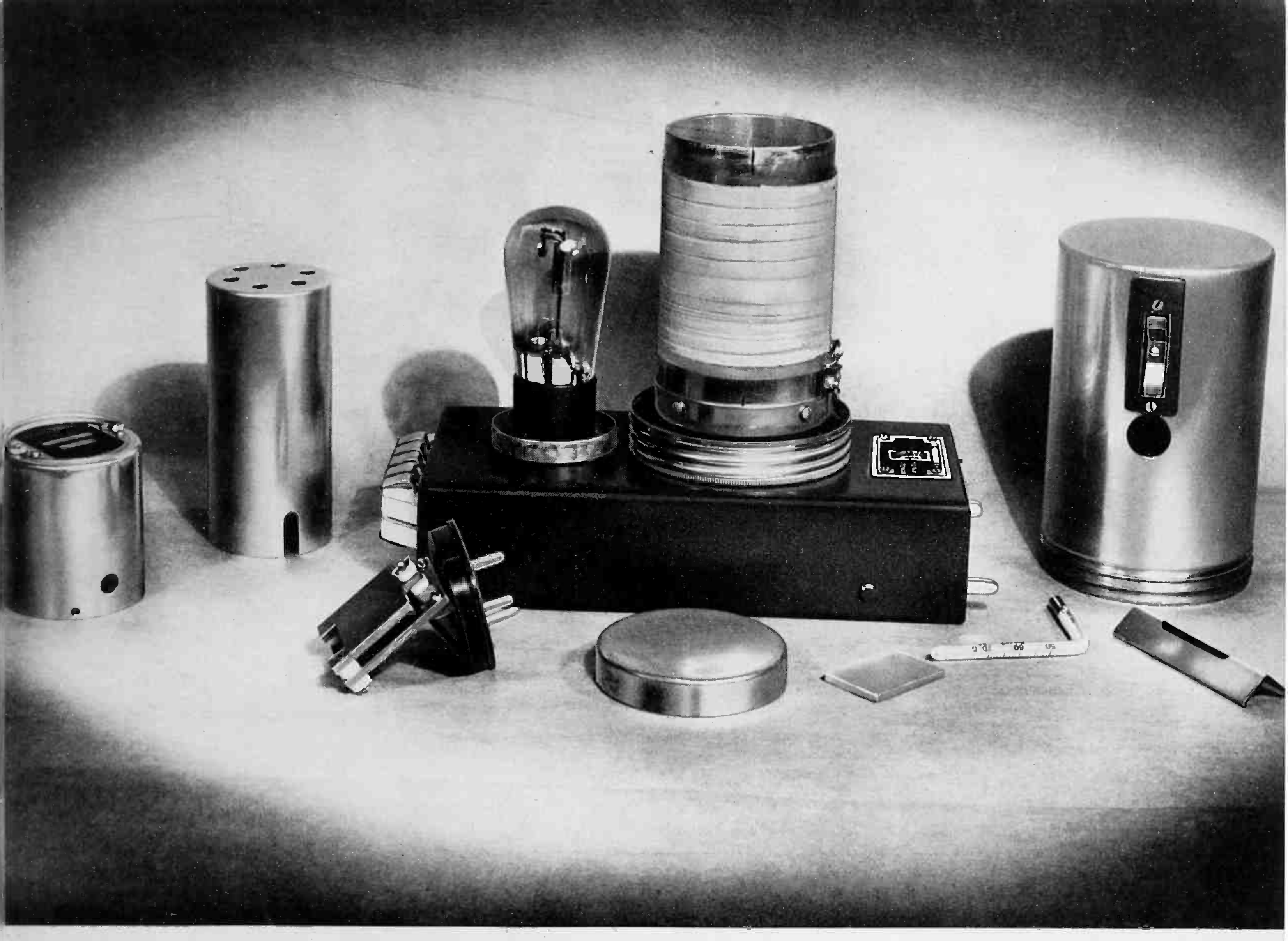

The new 702 A Oscillator which becomes standard for all new Western Electric transmitters. Using the new low temperature coefficient AT cut quartz plate, the Oscillator has a stability within 10 cycles. Above: Component parts of the Oscillator. Lower left: Side view showing plug-in connections. Center: Phantom view showing how crystal holder plugs inside oven. Right: View showing how thermometer is mounted.

702A OSCILLATOR

MASTER of Megacycles

Up Goes the 304 B with High Efficiency even into the Realm of 300 MC

By C. E. FAY

Vacuum Tube Development,
Bell Telephone Laboratories

In the past few years, considerable attention has been devoted to the development of radio communication at the ultra-high frequencies. As the available channels in the lower frequency range become assigned, this high-frequency portion of the radio spectrum, including frequencies higher than 30 megacycles, offers an abundant supply of additional channels. Developments have not progressed sufficiently, however, to give knowledge of the full possibilities of these higher frequencies. To be able to carry on studies of communication systems that may employ them, it has been necessary to develop vacuum tubes that will oscillate and amplify in this ultra-high frequency region.

Difficulties have been encountered in operating the conventional vacuum tubes at these higher frequencies. One of these is a reduction in efficiency as the operating frequency is increased. For ordinary tubes, the efficiency does not decrease to any great extent for frequencies below 15 megacycles. At frequencies somewhat above 30 megacycles, however, it begins to fall off rapidly, until a point is finally reached where the maximum allowable energy must be dissipated in the tube elements to produce any detectable output power. This is known as the frequency limit of the tube.

One of the causes of this decrease in efficiency with increasing frequency is that the charging currents to the inter-electrode capacitances increase in proportion to the frequency. Since these charging current must flow through the tube leads, which are not ordinarily designed to carry heavy currents, a considerable energy loss results, which decreases the useful output. These capacitances and charging currents are indicated by the dotted lines of Figure 1.

Besides its reduction caused by excessive charging current, the efficiency of a vacuum tube falls off very rapidly as the time of a period of oscillation approaches the time required for electrons to travel from the cathode to the anode. Reduction in efficiency due to this effect begins to be noticeable for most tubes at frequencies between 30 and 60 megacycles. Its most obvious cause is a lagging in phase of the plate current with respect to the plate voltage, although other and more involved effects are present.

Still another difficulty in the operation of the ordinary tubes at very high frequencies is the magnitudes of the inductances and capacitances within the tube relative to those of the external circuit. The capacitances and inductances within the tube itself are fixed in magnitude, but at ordinary frequences

Filament Voltage	7.5 Volts
Filament Current	3.25 Amperes
Maximum D.C. Plate Voltage—Unmodulated	1250 Volts
Maximum D.C. Plate Voltage—Modulated	1000 Volts
Maximum D.C. Plate Current	0.10 Ampere
Maximum Continuous Plate Dissipation	50 Watts
Maximum D.C. Grid Current	0.020 Ampere
At a Plate Voltage of 1250 Volts D.C. and Plate Current of 0.40 Ampere:	
Amplification Factor	11
Grid Plate Transconductance	2000 micromhos
Plate Resistance	5500 ohms
Inter-electrode Capacitances:	
Grid to Plate	2.5 Micro-micro-farads
Grid to Filament	2.0 Micro-micro-farads
Plate to Filament	0.7 Micro-micro-farads

Characteristics and Ratings of the 304 B Vacuum Tube

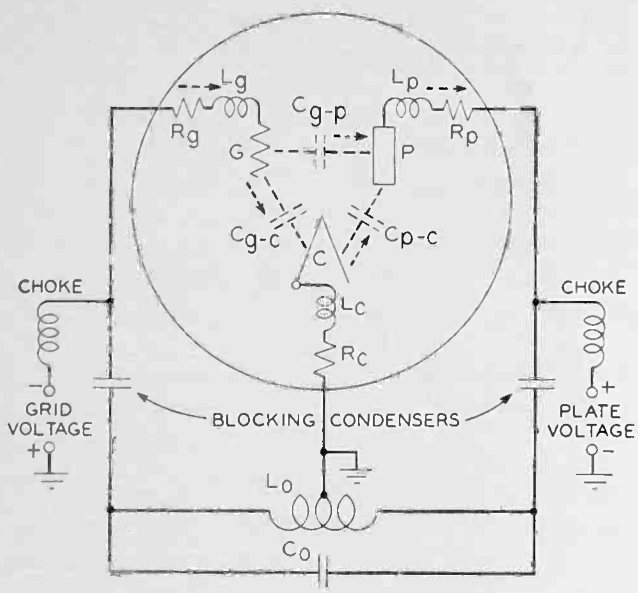

Fig. 1—Diagrammatic arrangement of vacuum tube oscillator circuit showing external and internal reactance.

are very small compared to the external reactances, such as L_0 and C_0 of Figure 1. To tune the circuit to a higher operating frequency, however, L_0 and C_0 must be made smaller, and a frequency is ultimately reached at which they become small compared to the inductances and capacitances of the tube. In extreme cases the tube reactances themselves control the oscillating frequency.

To avoid these difficulties that arise when ordinary tubes are operated at ultra-high frequencies, a tube has been recently developed in which these frequency limitations have been eliminated to such an extent that the tube is suitable for operation in the range from 30 to 300 megacycles. This tube, known as the Western Electric 304 B, is a low power triode suitable either as an oscillator or an amplifier. Its characteristics and ratings are given in the tabulation. At frequencies up to 100 megacycles it may be operated at full rating, but with higher frequencies the output is gradually reduced. The power output and efficiency of this tube in the range from 50 to 400 megacycles is shown by the curves plotted in Figure 2.

Several modifications have been incorporated in this new tube to make it suitable for operation at the higher frequencies. Dissipation of energy in the leads due to excessive charging current is avoided both by decreasing the inter-electrode capacitances and by decreasing the resistance of the leads. The grid and plate electrodes are supported by short, heavy wires which pass through the top of the hard glass envelope. These serve both as supports and lead-in wires, and provide a construction giving the low inductance and resistance essential to the operation of the tube at ultra-high frequencies. This construction has the further advantage of eliminating any solid dielectric other than the glass envelope. In a high-frequency field, solid dielectric absorbs energy and may break down, so that its elimination is desirable.

Besides these modifications, the charging currents themselves have been made very small by employing smaller electrodes. In general, the size of the anode is determined by the amount of heat that must be radiated, which for any given material is a function both of its operating temperature and its radiating area. In the original tube of this type, the 304A, a graphite anode was used because of its desirable heat radiating properties. After considerable testing and comparison it was found that a metal anode improved the life of the tube without any sacrifice of its essential characteristics. In addition an increase in efficiency at the high frequency limit of the tubes' oscillating range was obtained, because of the lower resistivity of the metal compared to carbon. The 304 B tube is now being manufactured with a molybdenum plate. The plate is cylindrical in shape and of relatively small diameter. The necessary surface for heat radiation is obtained by the use of three large radial fins, and all exterior surfaces are roughened to improve the radiating properties of the material.

This tube is being used very successfully by both amateur and commercial stations, and by others desiring a source of ultra-high frequency power at frequencies up to 300 megacycles. It has been used with particular success by the amateurs in their 28, 56 and 112 megacycle bands. At 112 megacycles it is possible to generate a carrier power of nearly 100 watts with two 304 B tubes in a push-pull oscillator circuit.

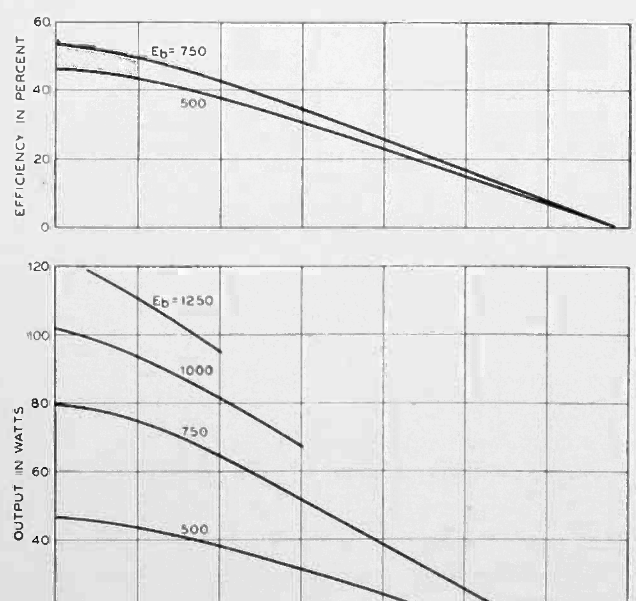

Fig. 2—Output and Efficiency of two 304 B tubes in a push-pull circuit.

Stabilized Feedback

New Control Principle Produces High Stability and Fidelity and Eliminates Distortion in Amplifiers

By H. S. BLACK

Member, Technical Staff, Bell Telephone Laboratories

Feedback is the action which may take place when a portion of the output of a transmission device, such as an amplifier, is returned to its input. The feedback can be either positive or negative, that is, in a direction either to increase or to decrease the amplification. Stabilized feedback employs the negative feedback principle in a new and revolutionary manner to actually control the properties and characteristics of wave transmission systems. So powerful and adaptable is this new control that even inexpensive amplifiers can easily be made to produce remarkable stability, high degree of fidelity, and absence of distortion and noise heretofore unobtainable even in the most carefully designed and expensive systems.

If to a typical vacuum tube amplifier fed from a source of input waves to be amplified such as signal waves, we add a suitable coupling or other path for returning some of the output wave to the input, it is evident that the waves appearing on the grid of the first tube come from these two circuit branches. Thus there are three waves to be considered in relation to the input side of the amplifier:

1. The incoming or signal wave.
2. The fed-back wave.
3. The voltage wave on the first grid, which is the algebraic sum of 1 and 2.

A primary consideration of course is whether the fed-back wave is positive or negative. Both types of feedback have been utilized heretofore and are more or less familiar to those in contact with radio. The regenerative amplifier and the oscillation generator are good examples of positive feedback. In the regenerative amplifier the output current remains under control of the incoming signal and must follow its variations while in the oscillator the wave circulating around the regenerative loop is self-determining subject only to circuit elements.

Until the advent of stabilized feedback the principal use of negative feedback has been in the "neutralization" of radio frequency amplifiers, being employed here to overcome the inherent tendency toward self-oscillation due to positive feedback through inductive or capacitative coupling of elements of the input and output circuits which exists even though great care in design is exercised to reduce such coupling. These effects become more pronounced as the frequencies become higher and are often of such a nature as to place a definite limit on the amount of amplification that can be utilized.

It should be emphasized that negative feedback as heretofore commonly applied in radio frequency amplifiers has had as its purpose the reduction or cancellation of inherent positive feedback. If the negative feedback is increased from an infinitesimal amount in any given case, it reaches its optimum

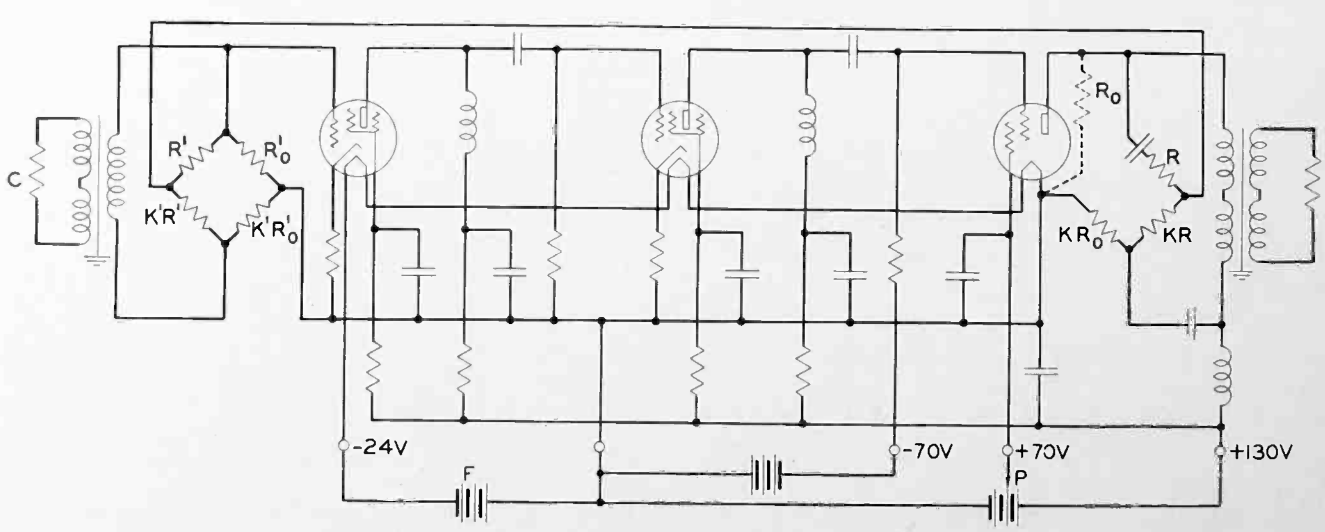

Fig. 1—Circuit of a negative feedback amplifier.

value in opposing positive feedback when it just equals the positive feedback. At that point the net or resultant feedback is zero and the effect is that of rendering the amplifier a strictly unilateral circuit having no feedback, positive or negative. In the prior art when larger amounts of feedback than required for neutralization were used the stability of the circuit as an amplifier was upset and this action was apt to make it a generator of oscillations. It was generally accepted therefore, that large amounts of feedback were physically impracticable.

In contrast to the use of negative feedback as discussed above, the stabilized feedback amplifier employs negative feedback in much larger amounts and for a different purpose. For stabilized feedback the negative feedback is increased to a value where it not only equals but greatly exceeds the amplitude of the wave that is effective on the first grid. In fact for large values of negative feedback, the fedback wave approaches equality with the incoming wave.

Thus a small wave effective on the grid controls a cycle of operations involving waves of much greater magnitude. Far from resulting in liability to self-oscillation, a technique has been discovered whereby the *greater the negative feedback ratio the more exact* is the correspondence in all respects between the output wave and the incoming wave, so that it may be said that the more complete is the control of the output wave by the incoming wave.

This action makes it possible to construct an amplifier having remarkable linearity of amplification and also great constancy of operating characteristics as regards the influence of circuit variables including the amplifying properties of the vacuum tubes used, fluctuations in power supply, etc. Such an amplifier will be less susceptible to noise and cross talk and possess improved phase and impedance characteristics. Certainly these types of amplifiers will be of the very greatest use and service throughout communication and allied fields.

The following example will be helpful in illustrating in a physical way how stabilized feedback in an amplifier improves the fidelity characteristics, often by an amount corresponding to the reduction in gain due to feedback.

It is generally accepted that the amplified signal wave in the output of an amplifier is accompanied by distortion produced in the tube. The ratio of this distortion to the signal can be assumed to be a function of the amplitude of the output signal, other things being equal and, with a given tube and circuit, as the signal output is increased, the percentage of distortion will increase.

In a simple system to which feedback can be applied but with no fed-back wave, the voltage effective on the grid is that of the incoming signal unmodified by feedback and there is a given amount of output signal and a given amount of unwanted distortion. If, now, negative feedback is gradually introduced in increasing amount and at the same time the incoming signal is increased by an exactly corresponding amount, it is clear that the voltage effective on the grid due to the signal alone remains unchanged, and that, therefore, the signal output remains unchanged in amplitude. By virtue of the negative feedback, however, some of the distortion is being fed back to the grid in such sense as to reduce the distortion appearing in the output. The result is less distortion with no diminution in signal output, a new improvement in linearity of the circuit.

The apparatus for increasing the negatively fed-back wave might be visualized as an amplifier of variable gain. Likewise, the apparatus for producing a corresponding increase in the signal input may be thought of as an amplifier of variable gain. Since the coordinated changes assumed to take place in these two amplifiers are a simultaneous increase in their amplifications by exactly equal amounts, the

(*Continued on Page Twenty-two*)

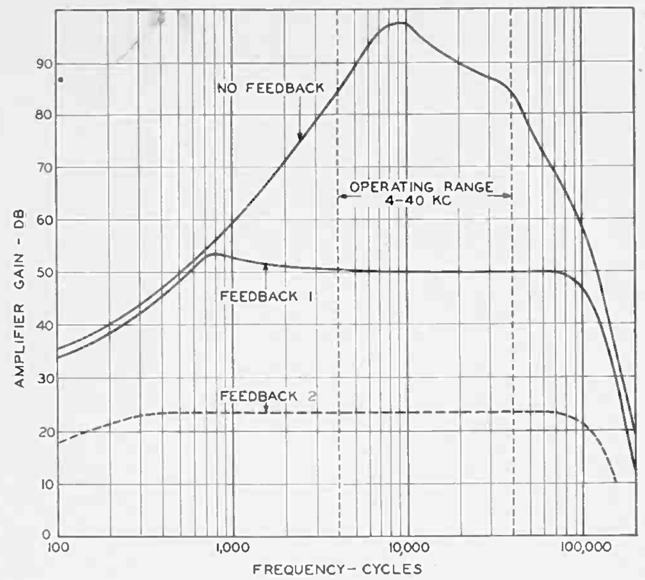

Fig. 2—Gain frequency characteristics with and without feedback of amplifier of Fig. 1.

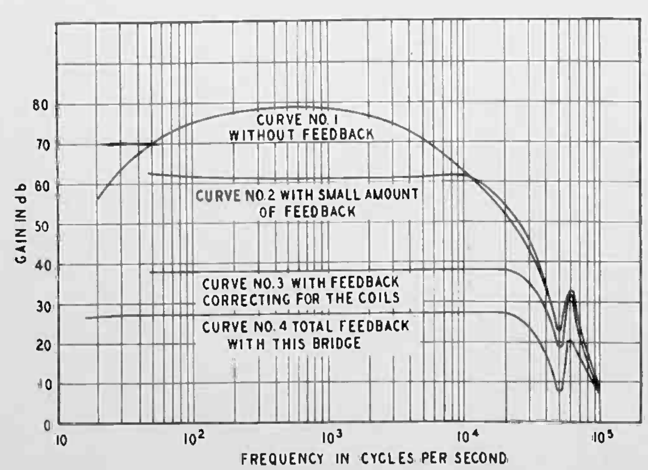

Fig. 3—Gain frequency characteristics with and without feedback of a voice frequency amplifier similar to Fig. 2.

New Aviation Receiver

A small, light weight radio receiver suitable for the private flyer and for emergency service in transport or mail planes has recently been designed by Bell Telephone Laboratories for the Western Electric Company.

The new receiver employs the superheterodyne principle and contains one stage of tuned radio-frequency amplification, two stages of intermediate-frequency amplification, and two stages of audio-frequency amplification. It will pick up signals in four separate frequency bands. One band is from 200 to 400 kilocycles (beacon and weather stations); one is from 550 to 1500 kilocycles (commercial broadcast stations) and the other two are high-frequency bands—from 1500 to 4,000 kilocycles (aircraft, police, amateur communications) and from 4,000 to 10,000 kilocycles (aircraft, amateur communications and foreign broadcast stations). The pilot selects the band desired by operating a four-position switch located on the front of the receiver. Such wide range application offers new possibilities for the use of radio in aviation and by police and other municipal, county, state and federal agencies.

The receiver is available in two forms coded the 20 A and the 20 B. The first is built for local operation with controls mounted directly on the front panel. It must be mounted within easy reach of the pilot. The 20 B is designed for remote control with a flexible extension shaft and a small control unit to be mounted wherever most convenient to the operator. With this arrangement the receiver itself may be installed in some out-of-the-way corner while the diminutive control unit may be mounted directly on the instrument board facing the pilot.

With a maximum undistorted output of 700 milliwatts the receiver will operate as many as six pairs of headphones simultaneously. Provision is made for converting the receiver for crystal-controlled reception in either or both of the high-frequency bands. When this is desired a two-crystal frequency control unit is incorporated. One of the crystals may be used in each of the high-frequency bands, or both may be used in the same band. This feature is often desirable when the receivers are used by commercial air lines, which have definite day and night frequencies for communication between air and ground and are not interested in receiving signals on other frequencies in the high-frequency bands.

Other important features are the "variator," a device for reducing loud static crashes when receiving very weak signals, and an automatic volume control which is normally used for all except beacon reception, where its use might interfere with course indication. A switch on the front of the receiver permits this automatic volume control to be cut in or out as desired.

Western Electric 20A Aviation Receiver

John H. DeWitt—WSM

After serving two years on the NAB Engineering Committee John H. DeWitt, Jr., was elected chairman of the committee on April 17, 1936. Although only 30 years of age DeWitt has been intensely interested in radio for 18 years. His entire career has been devoted to broadcasting. At 12 it was amateur radio that intrigued him. At 16 he had constructed the first broadcasting station in Nashville. Three years later, in 1925, he joined the staff of Station WSM, Nashville, where a Western Electric 1 kilowatt transmitter was being installed.

From 1927 to 1929 DeWitt was engaged in radio consulting work. His next move brought him to Bell Telephone Laboratories where he worked on the development of the 700 A Oscillator, the 1 A frequency monitoring unit and synchronization equipment. Perhaps while he was working in New York there still lingered a feeling of homesickness for the sunny skies of Tennessee, for in 1932, when WSM offered him the position of chief engineer he readily accepted and returned to Nashville.

DeWitt has been keenly interested in forwarding the cause of high fidelity broadcasting and has worked toward improving the coverage on clear channels. He has devoted many off hours to the study of vertical radiator characteristics and published a paper on the subject of fading from this type of antenna. In spite of the fact that there are only 24 hours in the chief's day and most of them are taken up with broadcasting he still finds time to do some long distance sightseeing through a telescope while pursuing his one hobby—astronomy.

Born in Nashville in 1906 DeWitt attended a local preparatory school, then, Vanderbilt University and later the University of Tennessee. In 1929 he married Ann Elise Martin also of Nashville. There is John H. DeWitt the third, age two, in the family who doubtless will attend the NAB Convention of 1956.

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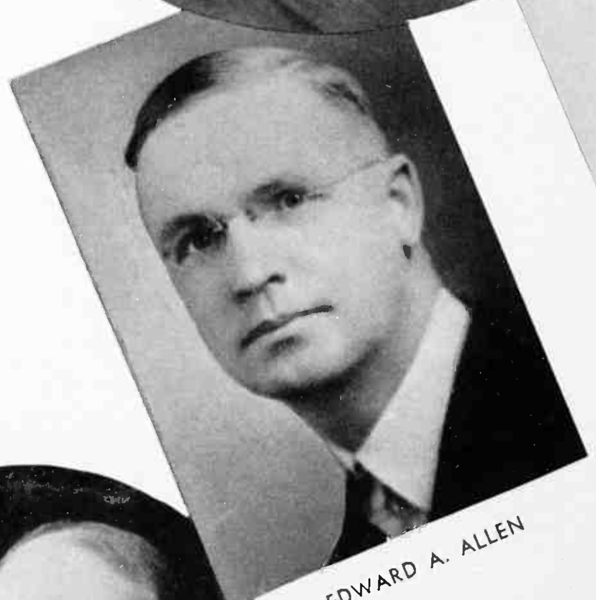
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(See Page Twenty-eight for Titles)

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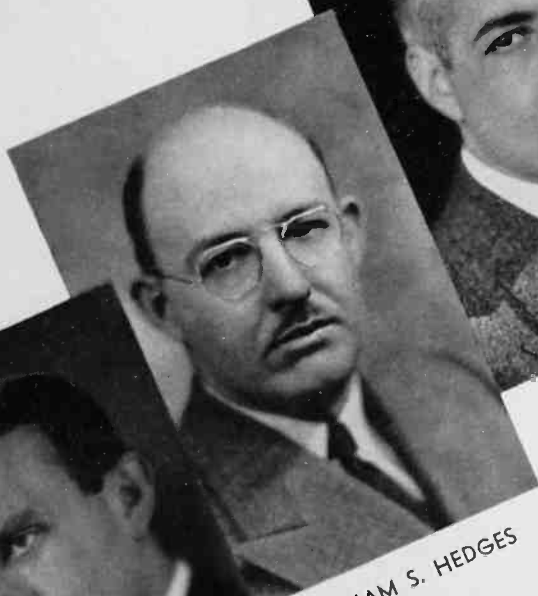

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J. H. DeWITT, JR.

Chicago Lakefront Showing Stevens Hotel, Setting for NAB Convention, July 6-8

Western Electric Exhibits Many New Radio Developments at NAB Convention

Huge Display to Occupy Two Entire Wings of 14th Floor of Stevens Hotel

When members of the National Association of Broadcasters meet in convention at the Stevens hotel, Chicago, July 6 to 8, they will witness many new developments in the art of broadcasting. Western Electric has taken two complete wings of the 14th floor of the mammoth hotel to exhibit its new equipment, some of which is the result of years of research by Bell Telephone Laboratories. Among the outstanding developments are:

Doherty High Efficiency Circuit — The Doherty circuit for high efficiency radio frequency amplification is one of the most outstanding contributions to radio thus far achieved. Applied to radio transmitters the Doherty Circuit effects a large reduction in power consumed. This new form of amplifier operates at constant high efficiency which does not vary with the percentage of modulation. In the past, 30 to 35 per cent efficiency has been the maximum that could be expected of the linear power amplifier stage in a high quality transmitter. Now efficiency as high as 60 to 65 per cent is a reality with this improvement. From this same standpoint it is also superior to systems employing high level modulation. The overall results of the application of this circuit are savings in space for equipment, reduced initial outlay for auxiliary equipment, economies in operation and maintenance and above all, a marked saving in power purchased. (A complete description appears elsewhere in this issue.)

100-250 Watt Radio Transmitter — This is a 100-250 watt high fidelity, all-AC operated transmitter which features stabilized feedback, low level modulation, low temperature coefficient quartz plate, radiation cooled tubes. The equipment is mounted as a single unit in a metal cabinet. (A complete description appears elsewhere in this issue.)

New Speech Input Equipment — A novel approach to a means for supplying the need for high fidelity, self-contained speech input equipment is found in this apparatus. Assembled as a single unit in an organ console type cabinet, low enough to mount on a standard table without obstructing the view of the operator, this equipment presents a rare combination of flexibility, simplicity of operation and high quality of performance. Compact assembly, the lack of inter-bay wiring, and ease of installation make it particularly suitable for use in studio installations, at semi-permanent remote pick-up points and as a companion to the new 100-250 watt radio transmitter.

Portable Speech Input Equipment — This is particularly designed for picking up programs

(*Continued on Page Twenty-one*)

KFJZ and KDLR Say OK for "8-Ball Mike"

According to recent reports Western Electric's new Non-directional Dynamic Microphone, launched on its broadcasting career some months ago, is sailing along on the crest of the wave. Word of the "Eight-Ball Mike's" performance over Texan waves, for instance, comes from Truett Kimzey, chief engineer of Station KFJZ, Fort Worth.

Says Chief Kimzey, "The new Western Electric Non-directional Microphone, now in use at KFJZ, is indeed one of the greatest steps that has been made for broadcasting stations in a technical way. We especially appreciate its use when we are broadcasting a program requiring several people to speak at one time. Its superior characteristics also are particularly noticeable when it is being used for soprano voices, as it will take care of the high pitched soprano voice in the best style."

Station KFJZ is owned and managed by R. S. Bishop who signed the first contract for the new microphone at the NAB Convention in Colorado.

More fan mail for the new microphone comes from Bert Wick, owner of Station KDLR, Devils Lake, North Dakota.

Mr. Wick writes, "The new 'Eight-Ball Microphone' is by far better than anything we have or ever have had. To say that we are satisfied is putting it mildly. In my personal opinion this new microphone is about as fine a piece of equipment as you have ever built. Of course, operation in conjunction with the Western Electric pre-amplifier makes it all the better.

"One thing we notice is its non-directional pick-up without discrimination and the beautiful reproduction of 'highs.' Particularly noticeable is the faithful transmission of the sound of the snare drums with their accompanying 'brushes' now so much used.

Bert Wick, owner of Station KDLR, Devils Lake, North Dakota, says a few words over the "Eight Ball Mike" about the "Eight Ball Mike" that are highly complimentary.

"The Riverside Hour" featuring Lee Downes' Orchestra and Nancy Jo Nolte, singer, broadcasting from KFJZ, Fort Worth, Texas. The Western Electric Non-directional Microphone (right) has received a gala welcome from the KFJZ family.

Really it is like the addition of another player in our seven-piece studio orchestra. As you know snare drums and their traps produce some high frequencies."

Marine Radio Saves Crew Aboard Sinking Schooner

When marine radio telephone saved the lives of ten men aboard the sinking schooner Fauci late last winter practically every form of electrical communication was brought into play. Telephone, telegraph, teletype and even a radio set in an automobile played a part in the dramatic sea rescue.

The first word of the Gertrude M. Fauci's predicament came to the operator of the New England Telephone and Telegraph Company's marine radio station at Green Harbor near Boston, when Captain Patrick McHugh's voice, spanning some 400 miles of the storm-swept Atlantic, said, "We have sprung a bad leak . . . we need assistance immediately!"

Realizing that there were no ships in the immediate vicinity of the Fauci equipped with radio telephone, the operator transferred the call to Coast Guard Headquarters at Boston. From here an "S O S" went out by radio telegraph in the hope that some nearby vessel could go to the sinking schooner's assistance. The cutter Cayuga off Cape Cod got the call and replied that they could probably reach the Fauci in 24 hours. This message was radio telephoned to Captain McHugh. He replied, "Doubt if we can last that long," and asked to have radio beacons operated at Sable Island and on Sambo Lightship.

Meanwhile news of the disaster winged over the country by telegraph and teletype. Newspaper headlines flashed the story. Broadcast stations interrupted their programs to tell of the doomed vessel. Charles M. Fauci, owner of the craft, picked up the announcement with his automobile radio set while driving through Springfield, Mass.

He was about to charter a seaplane to go to the aid of his ship when word came through that the trawler Lemberg was standing by. That night the Fauci sank. But the captain and crew were safe aboard the Lemberg. Later the Coast Guard cutter Cayuga brought them to shore.

The 702 A Oscillator

(*Continued from Page Eight*)

the circuit is that, within wide limits of frequency, it requires no adjustments of circuit elements to establish the proper conditions for oscillation and, as a consequence, the oscillator is inherently stable.

It is impracticable to lap quartz plates on a large scale to within 1 or 2 cycles of a designated frequency and, therefore, means are provided for making moderate changes in the frequency of the oscillator in order to establish exact frequency. The control for this frequency adjustment is in the form of a screw driver adjustment on the front of the oscillator and its setting is indicated on a dial visible through the top of the oscillator. The adjustment activates a worm drive mechanism with a high enough ratio to permit adjustment to zero beat to be attained at any frequency. This facility will enable the user to compensate for such frequency shifts as may occur if it becomes necessary to replace an oscillator tube.

The quartz in its mounting, coded as a 7A Quartz Plate, is a plug-in type of unit which is inserted in a socket inside of the oven of the 702 A Oscillator. The oven is of the double-wall all-metal type and employs a special bimetallic snap action thermostat to control the temperature which is nominally maintained at about 60° C. On account of its ruggedness and consequent reliability, the snap action type of thermostat is a noteworthy improvement over the mercury-in-glass variety used in the past.

It is true that it cannot be made as sensitive as the latter, but the need for sensitivity has been greatly reduced by the introduction of low temperature coefficient quartz plates. Furthermore, the snap action thermostat can control directly the supply of power to the heater thereby dispensing with the complicated and costly control circuits associated with mercury thermostats.

To enable the user to comply with regulatory requirements, a thermometer is provided to indicate the temperature in the vicinity of the quartz. As a further and more automatic safeguard, an alarm thermostat is provided which, in conjunction with external circuits, will give a positive indication of irregularities of the temperature control system. A pilot lamp on the transmitter panel which remains lighted as long as the temperature control circuits are functioning properly is employed as the indicator.

Figure 1 illustrates the manner in which the alarm functions. The left part of the diagram illustrates the sequence of events in the case of a power supply failure. At the time A, the power to the heater was removed and the temperature at the quartz dropped until at the time B the alarm thermostat acted to extinguish the pilot light. At this time the power was reapplied. On account of the time lag, the temperature at the quartz continued to drop even though the heat had been reapplied, but at C the temperaure at the alarm thermostat had again become high enough to actuate it and cause the pilot lamp to be relighted.

At time D the temperature at the oven thermostat had risen sufficiently so that it resumed control and subsequently the temperature at the quartz rose in the typical manner to its nominal value. The right part of the diagram illustrates the manner in which protection is obtained in the case that the control thermostat fails by remaining closed. This condition was simulated by short-circuiting the thermostat at the time E.

At time F the rising temperature, caused by the continued application of heat, actuated the alarm which extinguished the pilot light. The short circuit was then removed. At time G the temperature at the alarm had dropped sufficiently to cause

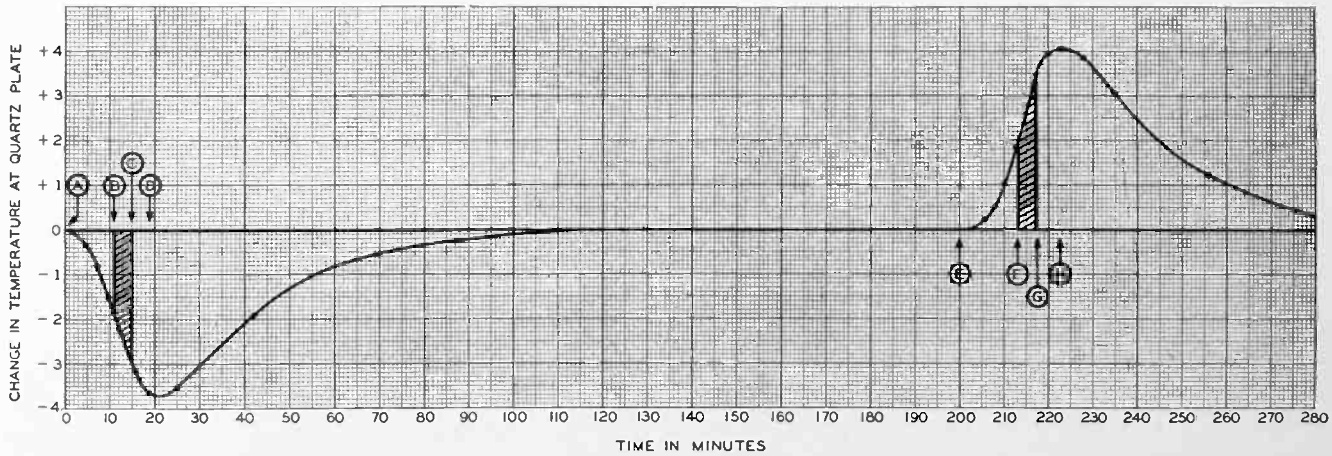


Fig. 1 — Operation of Alarm Thermostat in Western Electric 702 A Oscillator

A—steady state, heater power is removed. B—sub-temperature alarm operates, whereupon heater power is restored. C—sub-temperature alarm ceases to indicate. D—main thermostat opens for first time after heater power was restored. E—steady state at this point the main thermostat is shorted to create a condition of overheating. F—excess temperature alarm operates, whereupon main thermostat short is removed. G—excess temperature alarm ceases to indicate. H—main thermostat closes for first time after short was removed.

it to relight the pilot lamp, but the temperature at the quartz continued to rise until at time H the oven thermostat resumed control.

The time delay between a removal or application of heat, and the corresponding operations of the thermostats and the resulting drop or rise in the temperature at the quartz are caused by the capacity for heat storage inherent in the oven design. By properly selecting the heat storage capacity and other characteristics of the thermal paths between the components of a temperature control system, it is possible to reduce the fluctuations in the temperature of the quartz caused by the operation of the control thermostat. In the 702 A Oscillator these fluctuations — commonly referred to as the "thermostat cycle"—have a magnitude of only $\pm$ 0.075° C. or about one-tenth the sensitivity of the control thermostat.

Since increased thermostat sensitivity can only be obtained at the expense of ruggedness, this method of obtaining accurate temperature control results in greater thermostat reliability. The choice of the above-mentioned design parameters also influences the magnitude of the change in the temperature of the ambient necessary to cause a one degree change in the temperature at which the quartz is maintained. The ratio of these two temperature changes is a direct measure of the effectiveness of a temperature control system and is called its control ratio.

In the 702 A Oscillator the control ratio is greater than 35 to 1. In general, the greater the stability of the temperature at the quartz with respect to changes in the ambient temperature, the greater will be the lag or time delay with respect to all temperature changes. The existence of a lag is therefore evidence of inherent stability of the temperature control system, while the restriction of the lag to a reasonable period is indicative of the soundness of the design.

The probable poorest performance of an oscillator can be estimated by assuming that all of the variables which can effect its stability occur simultaneously and cumulatively. The figure thus obtained —the "deviation capability"—is presumably the greatest variation to be anticipated from the causes considered. Assuming the maximum temperature coefficient of the quartz to be 3 cycles in a million per degree Centigrade, the maximum frequency departures at 1500 kilocycles will be as follows:

$\pm$ 25° C. Ambient Temperature Change	3.20
$\pm$ 10% Plate Supply Change	0.15
$\pm$ 10% Filament Supply Change	0.15
Thermostat Cycle	0.34
Circuit Changes	0.10
Load Changes of 10%	0.10
Deviation Capability	4.04 cycles

It will be evident, therefore, that the maximum deviation should not exceed 4 cycles at 1500 kilocycles or 1.3 cycles at 500 kilocycles. Under ordinary operating conditions, these deviations may be much smaller and the introduction of the 702 A Oscillator inaugurates a new frequency standard.

Western Electric Exhibit

(*Continued from Page Eighteen*)

on location at a distance from the main or auxiliary studios of a radio station or network. It provides complete operating facilities and yet is light in weight and small enough to be conveniently handled and quickly set up. The program quality is comparable to that of standard studio equipment. Circuit features are stabilized feedback, mixing circuits for four microphones, two output lines with key switching, AC or DC operation.

94 A Amplifier — This new amplifier offers an economical means of eliminating complicated switching and volume control circuits. It overcomes lack of flexibility and crosstalk difficulties inherent in high level distribution monitoring systems of the single amplifier type used in broadcasting studios. With amplifiers of this type a monitoring or loud speaker system can be arranged to have practically unlimited flexibility. Due to low cost a separate 94 A Amplifier may be used economically with each loud speaker in such a system instead of providing initially one large amplifier with sufficient capacity for an ultimate number of loud speakers. The amplifier capacity of the system may be increased when required by adding additional circuit units, each composed of a loud speaker and associated 94 A Amplifier.

279 A Equalizer Panel — This new panel and the 23 A Equalizer have been designed to correct the non-uniformity of transmission, in the range from 35 to 8,000 cycles per second, of non-loaded telephone cable circuits employed for the transmission of high quality program material.

Program Line Terminating Panel — Here is a panel intended for terminating incoming and outgoing loops in broadcasting studios or transmitting stations. It provides terminating facilities with a maximum of two incoming and two outgoing lines.

265 A Gain Control Panel — This is a gain control panel for use with speech input amplifiers. It provides attenuation changes from zero to 36 db in 18 steps of two db each.

Other Western Electric radio broadcasting products on display are: 272 A Program Line Panel, 271 A Switching Panel, 268 A Order Wire Panel, 269 A Attentuator Panel, 270 A Output Switching Panel, 2—630 A Microphones, 993 B Mounting Plate with two 23 A Equalizers and a broadcasting vacuum tube exhibit.

The tube exhibit covers three families of vacuum tubes, comprising complete lines of transmitting types such as rectifier tubes, air-cooled amplifier tubes and water-cooled tubes. Featured among the latter group is the recently developed 100 kilowatt tube and the unique mounting which permits extremely rapid tube change. Experimenters will be particularly interested in the transmitting tube designed for operation at frequencies as high as 750 megacycles.

Stabilized Feedback

(*Continued from Page Thirteen*)

next step in developing the picture is to visualize these two amplifiers as one and the same amplifier through which both the incoming signal and the feedback wave are transmitted.

This amplifier can be pictured as introduced just ahead of the existing amplifier, but after the *junction* of the incoming and the feedback circuits, or it is obvious that the original and added amplifier can be considered as a single amplifier the same as the original but with increased amplification.

Thus the distortion in a given circuit can be reduced relative to the signal by first adding a negative feedback and then adding to the total gain of the amplifier, still keeping the amplitude of the signal effective on the grid of the final tube the same as before and, consequently, the signal output the same. In other words, the gain in the amplifying path is increased but the increase is nullified by a negative feedback.

This illustrates in a non-technical and approximate way how noise and distortion are reduced and greater linearity secured in an amplifier by stabilized feedback.

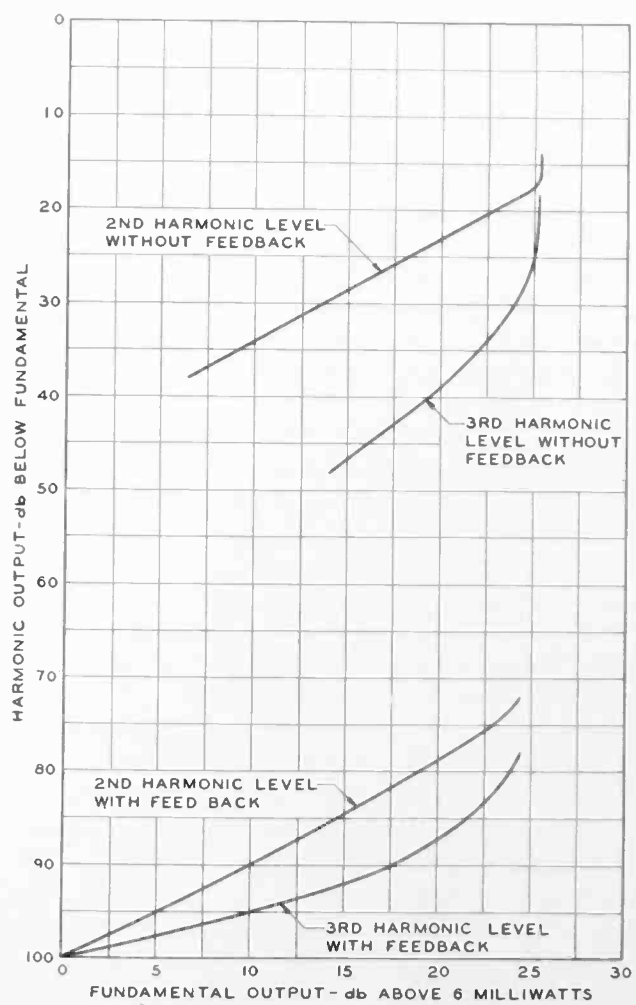


Fig. 4—Measurements of the second and third harmonic levels of an experimental amplifier.

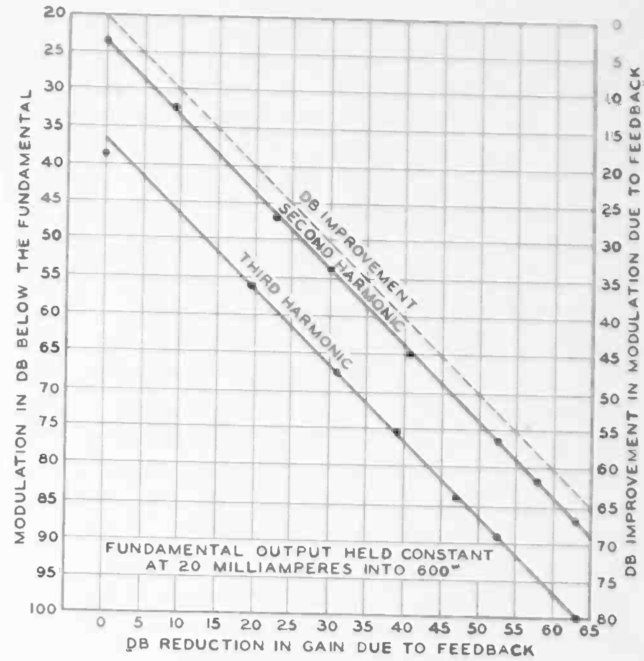


Fig. 5—Improvement of harmonics with feedback. One example of another amplifier in which with 60 db feedback, harmonic currents in the output are only one-thousandth and their energy one-millionth of the values without feedback.

The more important transmission features obtained by the use of a stabilized feedback circuit are:

1. Improved stability of gain and amplification.
2. Improved modulation.
3. Improved linearity (gain independent of input).
4. Improved and stabilized impedances.
5. Improved phase shift.
6. Reduced phase distortion.
7. Reduced variation of gain with frequency.
8. Reduction of noise generated within the amplifier or from power supply circuits.
9. The possibility of delivering constant voltage or constant current to a varying load or output impedance.
10. Reduction in the susceptance of the circuit to external fields or interference.
11. Improvement in load carrying capacity.
12. Practicability of using less precise and hence usually cheaper circuit parts without sacrifice of performance or reliability.

Stabilized feedback possesses a wide variety of other advantages which will be appreciated by practical designers of amplifiers, radio transmitters and receivers, and numerous other electrical systems.

Now-a-days vacuum tube and amplifier technique are such that mere gain (not power level) is relatively inexpensive. Therefore, it becomes economically desirable to build an amplifier whose gain is deliberately made higher than necessary and then to throw away the excess gain by feeding the output back on the input in such a way as to effect extraordinary improvement in constancy of amplification and freedom from non-linearity.

Generally speaking, the amount of improvement in each case is a function of the round trip gain in the amplifier and feedback circuits. If this gain is 60 db, the improvement in many of the items is of the order of 1000 to 1 and for a round trip gain of 26 db, the improvement is of the order of 20 to 1. By employing this feedback principle, amplifiers have been built and used whose gain varied less than 0.001 db with a change in plate voltage from 240 to 260 volts and whose modulation products were 95 db below the signal output at full load.

For an amplifier of conventional design and comparable size this change in plate voltage would have produced about .7 db variation while the modulation products would have been only 35 db down. A paper describing the general theory and operation of the stabilized feedback amplifier has been published by the writer.[1]

Figure 1 shows a typical stabilized feedback circuit presented for purposes of illustration there being of course a wide variety of other useful ways of returning a portion of the output to the input.

Figures 2 and 3 show clearly the improvement in the gain frequency characteristic with feedback as compared to without feedback.

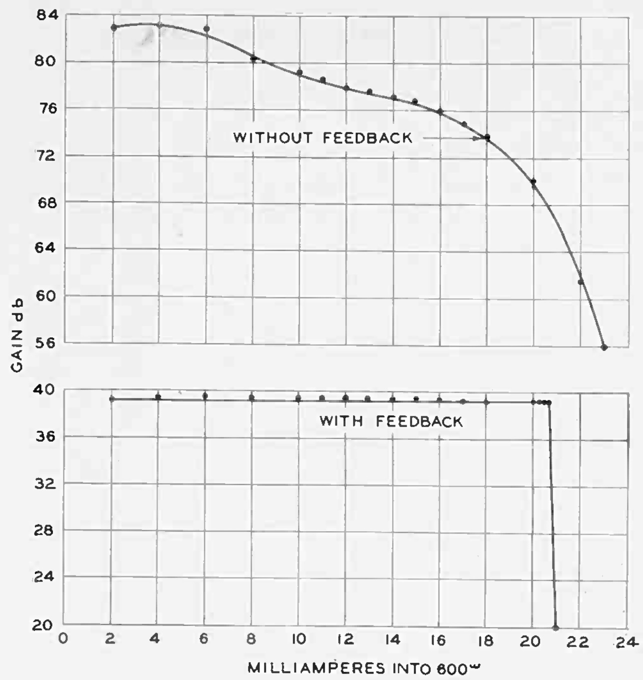


Fig. 7—Gain-load characteristic with and without feedback for a low level amplifier designed to amplify frequencies from 3.5 to 50 kc.

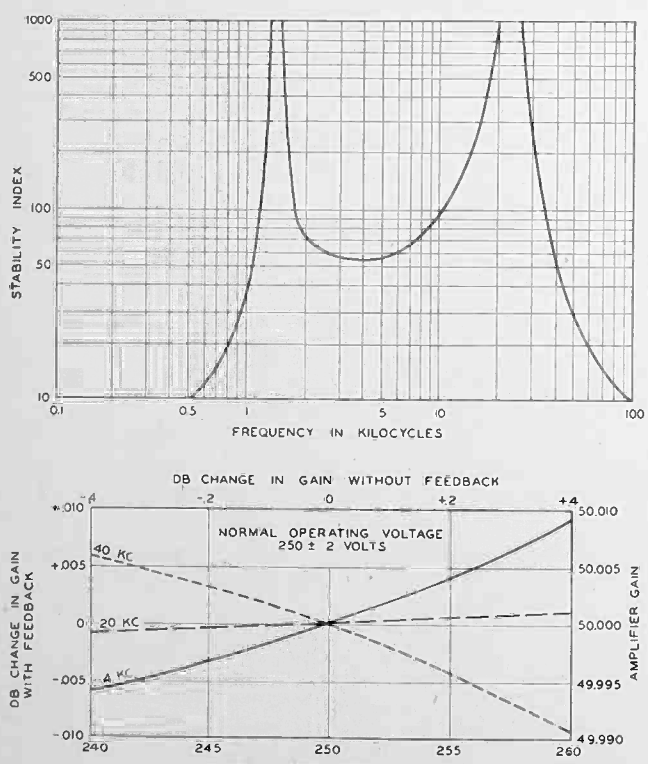


Fig. 6—Representative gain stability of a single amplifier as determined by measuring 69 feedback amplifiers in tandem at Morristown, N. J.

The upper figure shows the absolute value of the stability index. It can be seen that between 20 and 25 kc the improvement in stability is more than 1000 to 1 yet the reduction in gain was less than 35 db.

The lower figure shows change in gain of the feedback amplifier with changes in the plate battery voltage and the corresponding changes in gain without feedback. At some frequencies the change in gain is of the same sign as without feedback and at others it is of opposite sign and it can be seen that near 23 kc the stability must be perfect.

Figure 4 is an example of the reduction in harmonic production due to feedback. Measurements on a class A amplifier, as given by Figure 5, will show how the improvement may correspond exactly to the gain reduction. In general a point will always be reached by sufficiently increasing the negative feedback such that further increase in negative feedback reduces the harmonics db for db.

The ability of feedback arrangements to improve the linearity and stability of an improper amplifier by stabilized feedback is of great economic as well as technical importance. The attainment of high power and high quality together in an amplifier or radio transmitter has always been an object of especial desire since the power stage or stages are the most expensive to construct and operate. To make tubes in such stages larger so that a specified output would represent a smaller load in comparison to their full load capacity has been a costly expedient from both standpoints.

The utilization of negative feedback action improves the characteristics of the power stage by adding gain at a lower power level part of the system, namely, at the input, which can be done cheaply and by adding negative feedback as already explained. Thus, the same power stage can be operated with greatly improved characteristics or a much smaller power stage can be operated with equivalent quality of output.

Figure 6 shows how the stability is likewise improved by stabilized feedback. The stability index referred to in this figure is the ratio of the percentage change in amplification without feedback

(*Continued on Next Page*)

Stabilized Feedback

(*Continued from Preceding Page*)

to the percentage change in amplification with feedback. For even larger values of negative feedback the stability is unbelievably improved until the mere task of measuring it requires special technique.

Figure 7 indicates the effectiveness with which the gain of a feedback amplifier can be made independent of variations in input amplitude up to practically the overload point of the amplifier.

Speaking generally, feedback action is not limited to electrical amplifiers but is applicable to any kind of wave transmission and the resultant impulse may be transmitted back to the original point of action through mechanical, electrical, magnetic, thermal, or acoustical systems or by optical or electromagnetic waves of any suitable length or any combination of these systems.

In addition, the form, frequency, and amplitude of the impulse may vary in any conceivable manner consistent with stability requirements[2] in going through the loop transmission path. The necessary condition is that the impulse be returned eventually to the point of action (input) with the same frequency and in the same form as the excitation. As an illustration of some of these points the paper by Mr. Kishpaugh in the May issue of PICK-UPS shows the application of stabilized feedback to a radio transmitter. Here it is to be noted that the frequency is translated twice in once traversing the closed feedback loop.

The use of stabilized feedback as a new tool in the design of radio transmitters is a good illustration of its applicability to wave transmission systems in general. One aspect deserves special mention. From the standpoint of those responsible for operating and maintaining station equipment, it is interesting to note that the amount of feedback used is determined during the technical development of the circuit of the transmitter. It is fixed at that time once and for all and, hence, no matter what the operating condition of the transmitter, the many improvements in quality, improved load capability, stability, and reduced noise are at all times obtained automatically without any maintenance adjustment whatsoever.

Technically, it is equally interesting to note further that feedback action at all times will in addition cause the high level high power tubes to adjust themselves automatically to the theoretically optimum operating point on their dynamic characteristic irrespective of tube changes including aging or variations in grid bias.

[1] "Stabilized Feedback Amplifiers," by H. S. Black, presented at Winter Convention of A.I.E.E., New York City, Jan. 23-26, 1934. Published in "Electrical Engineering" Jan., 1934, and in "Bell System Technical Journal." Also "Feedback Amplifiers," by H. S. Black, "Bell Laboratories Record," June 1934.

[2] "Regeneration Theory," H. Nyquist, "Bell System Technical Journal," Vol. XI, pp. 126-147, July, 1932.

New 100-250 W. Transmitter

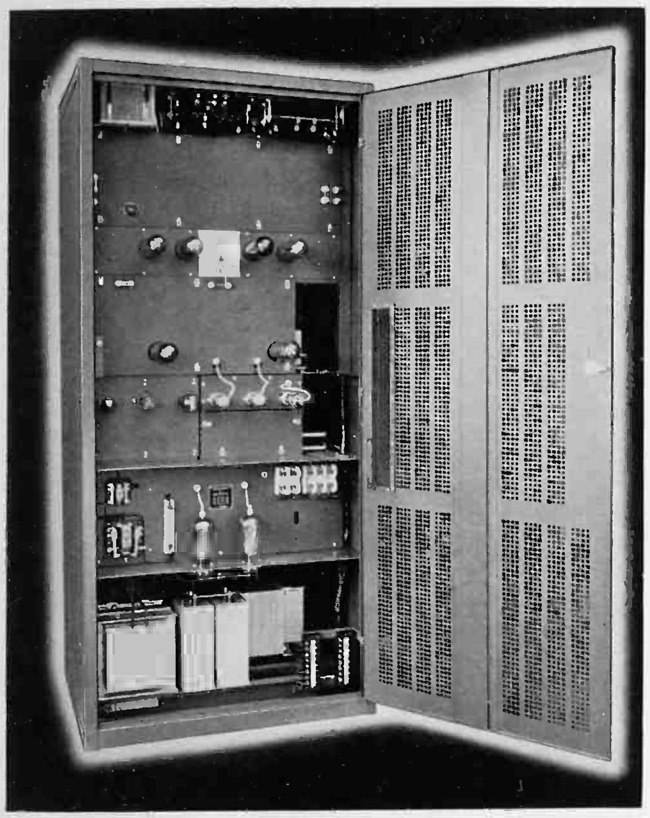
(*Continued from Page Seven*)

of feedback as it is now generally appreciated. The feedback circuit makes it possible to operate all of the vacuum tube filaments from alternating current and still have the carrier noise more than 60 db below 100 per cent modulation when measured without regard to any weighting effect and nearly 80 db below 100 per cent modulation when measured through a weighting network which simulates the discrimination of the ear for the noise frequencies.

Performance of the transmitter as far as any high fidelity requirements are concerned is very satisfactory. The total distortion is less than 2 per cent over the important frequency band. The data taken for frequencies above 2,000 cycles has little practical significance although of interest technically. It has been shown that the energy in a program lies to a large degree below 1,000 or 2,000 cycles, and actual modulation of more than 10 per cent at 5,000 cycles due to program material is almost an impossibility. These measurements indicate that the performance of this equipment will meet any high fidelity standard.

PERFORMANCE CHARACTERISTICS OF THE No. 23 A RADIO TRANSMITTER

Power Output	100 watts, 250 watts or 100/250 watts
Frequency Range	550 to 1,600 kilocycles
Power Input	2,200 watts, 50 or 60 cycles, 110/220 volts, single phase
Speech Input Level	About 6 milliwatts single frequency
Program Level	About — 6 decibels
Frequency Response	30—10,000 cycles within ± 0.5 decibel with reference to 1,000 cycles
Total R.M.S. Harmonic Distortion (400 cycles)	250 watts output—less than 1.5% at 100% modulation
Total R.M.S. Noise	60 decibels below 100% modulation
Weighted Noise	80 decibels below 100% modulation
R.F. Harmonics	More than 70 decibels below carrier level
Possible Program Level Range	More than 60 decibels
Stabilized Feedback	Yes
Antenna Coupling Unit for Concentric Transmission Line	Yes
Antenna Resistance Range	20 ohms to 200 ohms
Antenna Reactance Range	+ 200 to — 200 ohms
Tube Cost	$210 approximately
Operating Cost	Less than 15 cents per hour



Rear view of 23 A Transmitter showing availability of all vacuum tubes.

If one takes the performance at 400 cycles as representative of the actual performance of the equipment, and this incidentally is the usual method of determining performance, this transmitter exceeds the high fidelity requirements proposed by the Engineering Department of the Federal Communications Commission by approximately ten times.

Knowing the value of appearance in broadcasting equipment, there has been no sacrifice made in this direction as may be seen from the photograph. Its general appearance is similar to that of the larger transmitters manufactured by the Western Electric Company. All tuning controls are arranged on the front of the transmitter and the meters, which are of the modern square type, are arranged just above eye level across the front of the transmitter. Enough meters are provided so that all important circuits can be under continuous observation, and a test meter reveals the condition of all of the less important circuits.

Opening the full length door on the back of the cabinet releases a safety switch which disconnects all high voltage from the equipment and exposes all of the vacuum tubes and every piece of equipment which it is ever necessary to reach quickly in case of trouble. All of the radio frequency coils and condensers are in adequately shielded compartments and are reached through the front of the transmitter. Since there is no necessity of adjusting these circuit elements after the transmitter has been initially tuned, doors have not been provided but the four front panels are readily removed for inspection.

The floor space taken up by the radio transmitter is so small (33″ x 28″) that it is ideal for installation in the same room with the speech input equipment and studio control apparatus. It is easily possible in a room not over 15 feet square to install all of the radio equipment associated with both the studio and the transmitter, as well as phonograph turntables and an operator's desk. This makes a splendid arrangement for the small station as the studios can be grouped around this central control room under the watchful eye of the station operator at all times.

The accompanying table gives some of the important statistics concerning the transmitter. It might be well to point out that the total power consumption of 2,200 watts at 250 watts output is somewhat of a reduction over previous equipments of this power.

New Graybar Manager

The Graybar Electric Company has appointed D. B. McKey to the position of district sales manager of broadcasting equipment sales with headquarters at Atlanta, Georgia. Mr. McKey will fill the vacancy left by the late W. F. Bartlett who passed away May 2, after a brief illness.

D. B. McKey

Mr. McKey has had long and varied experience in the field of communications. In 1914 he enlisted with the U. S. Navy and made the usual tours of duty with the fleet. He was made instructor in AC Theory at the Naval Radio School, and later became officer in charge of the Naval Aircraft Radio School at Great Lakes.

In 1923 he joined the American Telephone and Telegraph Company where he was assigned to the technical staff of station WEAF. After serving three years in this capacity he was transferred to the technical staff of Long Lines Department working with Bell Telephone Laboratories on the development of high frequency trans-Atlantic radio transmitters and antenna systems at Deal, N. J.

In 1928 Mr. McKey was transferred to the transmitting station at Lawrenceville, N. J., as resident engineer. He held this post for two years when he became a member of the technical staff at Bell Telephone Laboratories. For the following four years he was engaged in systems development work and flight tests of commercial airplane radio equipment at Hadley Field, N. J. During the past two years at the Laboratories, from 1934 to 1936, Mr. McKey has been working on the design and development of radio transmitting equipment for aircraft.

The Doherty Circuit

(*Continued from Page Four*)

into an impedance of 1000 ohms by virtue of the presence of the other. If one tube is removed, or prevented from contributing to the output, the remaining tube obviously works into an impedance of 500 ohms, which increases again as the inactive tube is permitted to resume a share of the load.

This being opposite to the effect desired, it is necessary only to insert, as shown in Figure 2, an impedance-inverting network between the load and the tube that is to remain in operation. Such networks are well known and have served numerous useful purposes. The input impedance of the network being inversely proportional to the terminating impedance, the load impedance to the first tube (designated Tube A) may be made 2000 ohms when the second tube is inactive, whereupon it will be gradually reduced to the desired value of 1000 ohms if the second tube is permitted gradually to come into action until the load is shared equally by the tubes.

The operation of the amplifier, then, is as follows: Tube B having a high negative grid bias, no output is obtained from it until the excitation on the amplifier exceeds a certain value, which is the value required to obtain the carrier power from Tube A. Tube A is made to furnish all instantaneous outputs between zero and the required carrier output, and behaves like a conventional linear amplifier up to this point. At the carrier output Tube A is furnishing only half the power of which it is capable, since each tube in a two-tube amplifier has to have a capacity of twice the carrier power to permit complete modulation; but since the effective load impedance is 2000 ohms this power is furnished at maximum alternating plate voltage and consequently maximum efficiency.

As the excitation on the tubes increases beyond the carrier point, Tube B begins to contribute power to the circuit, and the output of the amplifier increases by virtue of the combined effects of a rapidly increasing output from Tube B and a correspondingly rapid reduction of the load impedance to Tube A which permits the latter also to increase its output without having to increase its already high alternating plate voltage. At the instantaneous peak of a completely modulated wave each tube is delivering twice the carrier power into an effective load impedance of 1000 ohms, just as would be the case in the conventional amplifier circuit.

Figure 3 shows how the radio-frequency plate potentials and plate currents in the two tubes vary with grid excitation. The plate potential of Tube A attains nearly its maximum value at the carrier level and rises only slightly as the excitation increases from this point to the peak. The plate current of Tube B commences just before the carrier point is reached and rises rapidly to a peak value equal to that of Tube A. The remaining two quantities, the plate potential of Tube B and the plate current of Tube A, are representative of the output of the amplifier and are required to be linear with excitation.

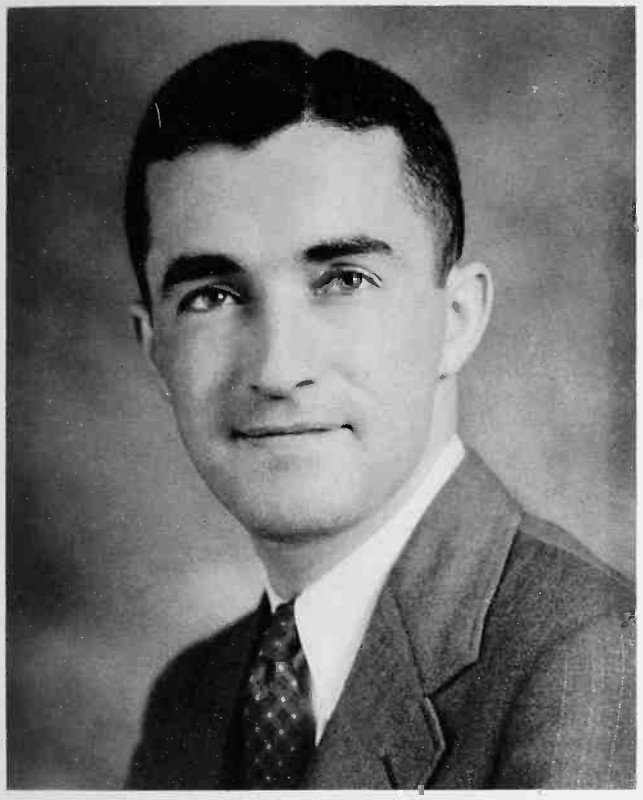
As the excitation on the amplifier varies about its average or carrier value in accordance with the modulation, the average or dc plate current of Tube A accordingly remains unchanged, while the average plate current of Tube B increases from zero or a small value with no modulation to approximately half that of Tube A with complete modulation. The total plate current, accordingly, increases about 50 per cent when the carrier is completely modulated, and since the average output likewise increases 50 per cent the efficiency is the same as with unmodulated carrier.

Figure 4 shows two typical impedance-inverting networks. Each consists of three equal reactances. Each, when terminated in an impedance Z, has an input impedance of X^2/Z ohms. One of the characteristics of all impedance-inverting networks is a 90-degree phase shift between the input and output terminals. The plate potentials of the two tubes of Figure 2 are therefore 90 degrees apart in phase, while in the conventional parallel circuit of Figure 1 the phase difference is zero, and in the conventional push-pull circuit the phase difference of course is 180 degrees.

Since the grid potential on a power amplifier tube is required to be opposite in phase to the plate potential, the grids of paralleled tubes are always excited in phase with each other, while in a push-pull amplifier a 180-degree phase difference is required between the grid potentials. Accordingly, in the new circuit a 90-degree phase difference is necessary, and is provided by employing in the grid circuit another network of the type illustrated by Figure 4.

The radio-frequency circuit of the amplifier then assumes the form shown in Figure 5. The coil connected from plate to plate is the series coil of Figure 4(a), giving a 90-degree phase retardation. The condenser from grid to grid is the series condenser of Figure 4(b), which introduces a compensating 90-degree phase advance and renders the total phase shift the same through both tubes to the load, so that both may be excited from the same source.

The circuit is strikingly similar to that of the conventional push-pull amplifier, the only apparent difference being that the input and output are single-sided rather than balanced. With the coaxial transmission line coming into general use for connecting transmitters to their radiating systems the single-sided circuit possesses a distinct advantage in simplifying the output circuit design and eliminating the necessity of coupling transformers.



William H Doherty

The saving in power and reduction in water cooling requirements made possible by the new mode of operation are illustrated by Figure 6, which shows the comparative plate input power and dissipation for a 50-kilowatt linear amplifier operated in the conventional circuit at 33 per cent carrier efficiency, and in the high-efficiency circuit at its nearly constant efficiency of 60 per cent. With the high-efficiency circuit the power input is reduced by a factor of almost two, and the dissipation by a factor of three, for the average percentage modulation of a broadcast program.

The first tests of the new circuit were carried out at about the time the negative feedback principle of H. S. Black, of Bell Telephone Laboratories, was first being applied to broadcast transmitters. It was immediately apparent that the remarkable improvements in amplifier performance made possible by the use of stabilized feedback could be turned to particular advantage in rendering unnecessary any critical adjustment for obtaining a satisfactory fit of the characteristics of the tubes over the modulation cycle.

In more than two years of experimental work during which the new amplifier circuit and the feedback principle have been employed at various power levels and various frequencies, both of these new developments have proved to be highly practical in application. Through their use it becomes possible to establish new standards of transmission quality with markedly reduced cost of apparatus and power.

William H. Doherty

A degree of B.S. from Harvard at the age of 20—an M.S. at 21 and at 29 an invention which promises to revolutionize radio frequency amplification—these are some of the notable achievements credited to William H. Doherty of Bell Telephone Laboratories. The invention which bears his name is known as the Doherty High Efficiency Amplifier Circuit. This new contribution to the art of broadcasting will be incorporated in radio transmitters manufactured by the Western Electric Company.

Mr. Doherty described the amplifier circuit in a paper read before the convention of the Institute of Radio Engineers held in Cleveland during May. Economies in radio broadcast plant equipment and power consumption which are possible through the use of this unusual improvement make it of vital interest to radio engineers, station owners, and all others concerned with the business of broadcasting.

After graduating from Harvard in 1927, Mr. Doherty joined the Bell System, starting his career in the Long Lines Department of the American Telephone and Telegraph Company. Subsequently he made studies of radio wave phenomena for the United States Bureau of Standards. In 1929 he joined the staff of Bell Telephone Laboratories where he has been engaged in the development of high-powered transmitters for transoceanic radio-telephone service.

During the past two years he has made some valuable improvements in high fidelity transmission. More recently he turned his attention to perfecting the Doherty circuit which has already revolutionized the design of new radio frequency amplifiers.

The youthful inventor was born in Cambridge, Mass., in 1907. Quite naturally he chose Harvard, his home town university, for his Alma Mater. Fellow engineers who burn the midnight current with Mr. Doherty at the Whippany experimental laboratory will tell you that radio research is his all-absorbing interest.

Carries On With Artificial Larynx

In 1930 E. L. Wolfe, who lives in Nutley, N. J., underwent an operation which deprived him of the power of speech. A successful salesman for 26 years, Mr. Wolfe had no intention of retiring. A Western Electric artificial larynx solved his problem, and for the last six years his business has increased 30 per cent each year, according to the Newark Sunday Call.

"I'm not trying to make the point," says Wolfe, "that the artificial larynx has improved my powers of persuasion. Business has improved, you know, and because I still have my voice I'm able to do justice to my job."

Edwin W. Craig—WSM

(*Continued from Page Three*)

ilar ideas as to the sphere and obligations of radio.

That Craig recognizes the obligations of broadcasting to its public is evident as soon as one begins to talk with him. "When the government gives an organization a share of the available broadcast band and a license to broadcast on a certain frequency, it has given to that organization a grant of inestimable value. The ether belongs to the people of the United States. The government is its trustee, consequently a government license or franchise to broadcast carries with it certain very definite and inescapable obligations to the public," says Craig.

"Unless a station lives up to those obligations, it is denying the people their proper service and sooner or later must relinquish its grant. To live up to its duties a station should not only provide entertainment but give unbiased information to the public; it should provide inspiration, strive to develop patriotism, and above all, should increase the public's desire for education by producing interesting programs of real educational value.

"Broadcasters must work endlessly to increase the quality of their programs. The worth of a program cannot be measured by sheer popularity alone. Too many advertisers and managers seem to believe that to command an audience they must concentrate on producing an uninterrupted supply of dance band music. I like that type of music, but I don't believe it should constitute so much of the total broadcasting time.

"Our job is not simply to entertain. If broadcasting is to survive and fulfill its destiny, every station manager and owner must concentrate on the job of giving listeners a more discriminating program, a type of program which will elevate the listener's own taste, and one that will develop his love for the best in art, music, literature and all the other things which go to make up a cultural existence.

"Radio is working toward these ends," says Craig. "Walter Damrosch has done much to elevate the public's appreciation of good music. The Radio Guild programs originated by the National Broadcasting Company are giving the public a new love of the drama. The broadcasts of the Better Speech Institute of America are helping to better the speech of our citizens. There should be many more such programs in all forms of the arts.

"Radio," he says, "however, has thus far failed to find the correct answer for radio and education. We must find a way to put education on the air in such a manner that it will be accepted by the listener and made profitable to him. We have not yet found the technique for doing that, but I am convinced that it can be done.

That problem consumes many of Craig's waking moments. He frankly admits that he does not know the answer. The voice of Station WSM goes out through the hills of Kentucky and Tennessee and throughout the far reaches of many other states where there are literally millions of people who are in direct need of education and inspiration. Furthermore, Nashville, known as the Athens of the South, is honeycombed with all types of schools and colleges. Here, then, is a laboratory with all the tools and equipment and vast trial grounds in which to experiment.

"We believe," says Craig, "that the interest of the home and the interest of the teacher meet at one point—in the child. Both have a common mission—to make a useful citizen of that child.

"With this as a cue, WSM is undertaking the development of a program structure that will act as a clearing house for the parent and the teacher. Problems common to both will be brought to the air, through proper radio technique, calculated to arouse in the family circle a degree of interest and enthusiasm equal to that of the professional teacher.

"It is apparent to us that educational programs which do not interest the family circle are destined for failure, and only serve to leave both the family listener and educator groups dissatisfied. Our new program to begin in September, we hope, will reach the level of interest where enthusiastic response is received from parents and teachers alike. That, we believe, will be one answer to 'education in radio.' "

Of the many things in radio Craig confesses puzzle him, perhaps he finds more amusement in seeking the reason for the continuous popularity of WSM's Saturday Night "Grand Ole Opry"—perhaps the nation's first "Barn Dance". It has been going strong for eleven years. Believing one week that listeners might relish a change, he announced that a different type of show would be broadcast the following Saturday. And then came a flood of 140,000 letters of protest. Listeners would not let him change that program! He has sought the reason—he has asked old heads in radio, program directors—he has even consulted a Vanderbilt University sociologist. Each has a theory; none has a clear-cut answer. He's still looking for that answer, and a lot of other answers. That's the sort of man Edwin Wilson Craig is.

NAB Official Family — See Pages 16-17

Leo J. Fitzpatrick, WJR .... President
C. W. Myers, KOIN-KALE .... First Vice-President
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Directors: Two-year Term

Alfred J. McCosker, WOR; Harry C. Butcher, WJSV; John J. Gillin, Jr., WOW; S. G. Persons, WSFA.

Directors: One-year Term

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Committee Chairmen

Arthur B. Church, KMBC, Commercial Committee and Audit Bureau Committee; John H. DeWitt, Jr., WSM, Engineering Committee; Lambdin Kay, WSB, Program Awards Committee.

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217 A Marine Radio Telephone Equipment
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(These bulletins will be furnished upon request)

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RADIO EQUIPMENT

Broadcasting Equipment and Accessories

Radio Frequency Distribution Systems

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- Transport Plane Two-Way Radio Telephone
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- One-Way Medium-Frequency Transmitters
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PUBLIC ADDRESS EQUIPMENT

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Announcing Systems
Program Distribution Systems — Records, Radio
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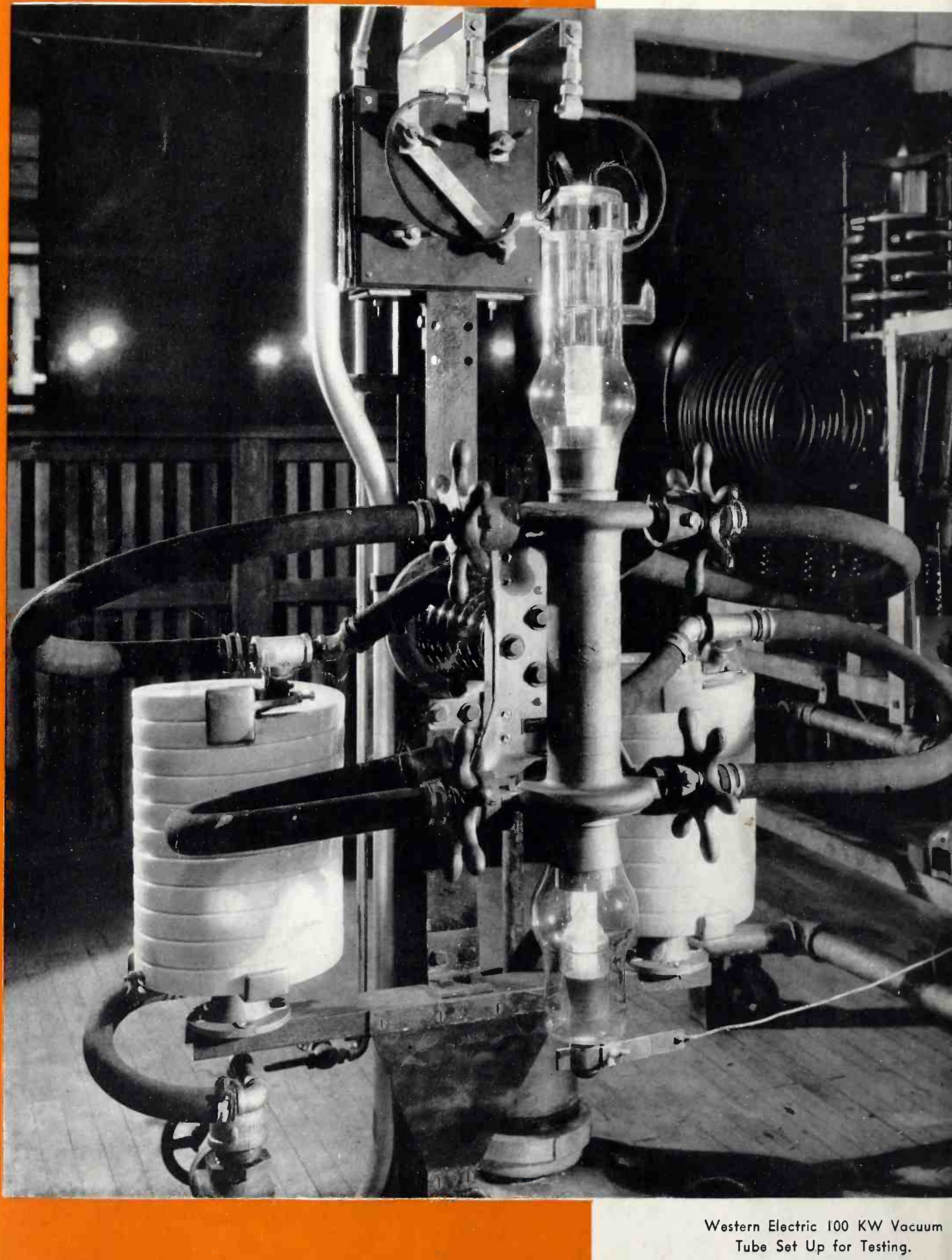

Western Electric 100 KW Vacuum Tube Set Up for Testing.