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By Projection Television
(See contents page)

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JANUARY
1939

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RADIO . . . COMMUNICATION AND INDUSTRIAL APPLICATIONS OF ELECTRON TUBES . . . DESIGN . . . ENGINEERING . . . MANUFACTURE

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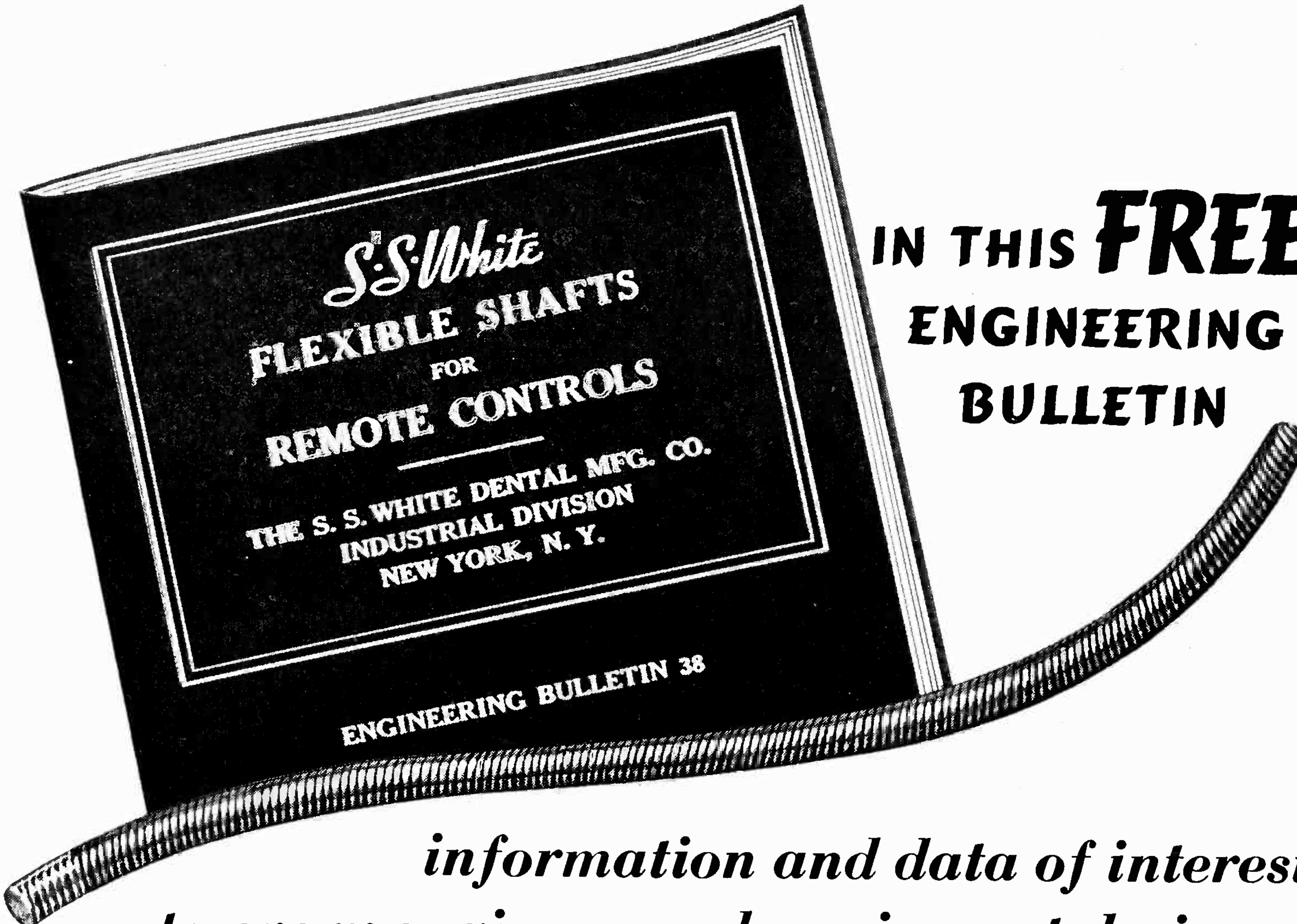

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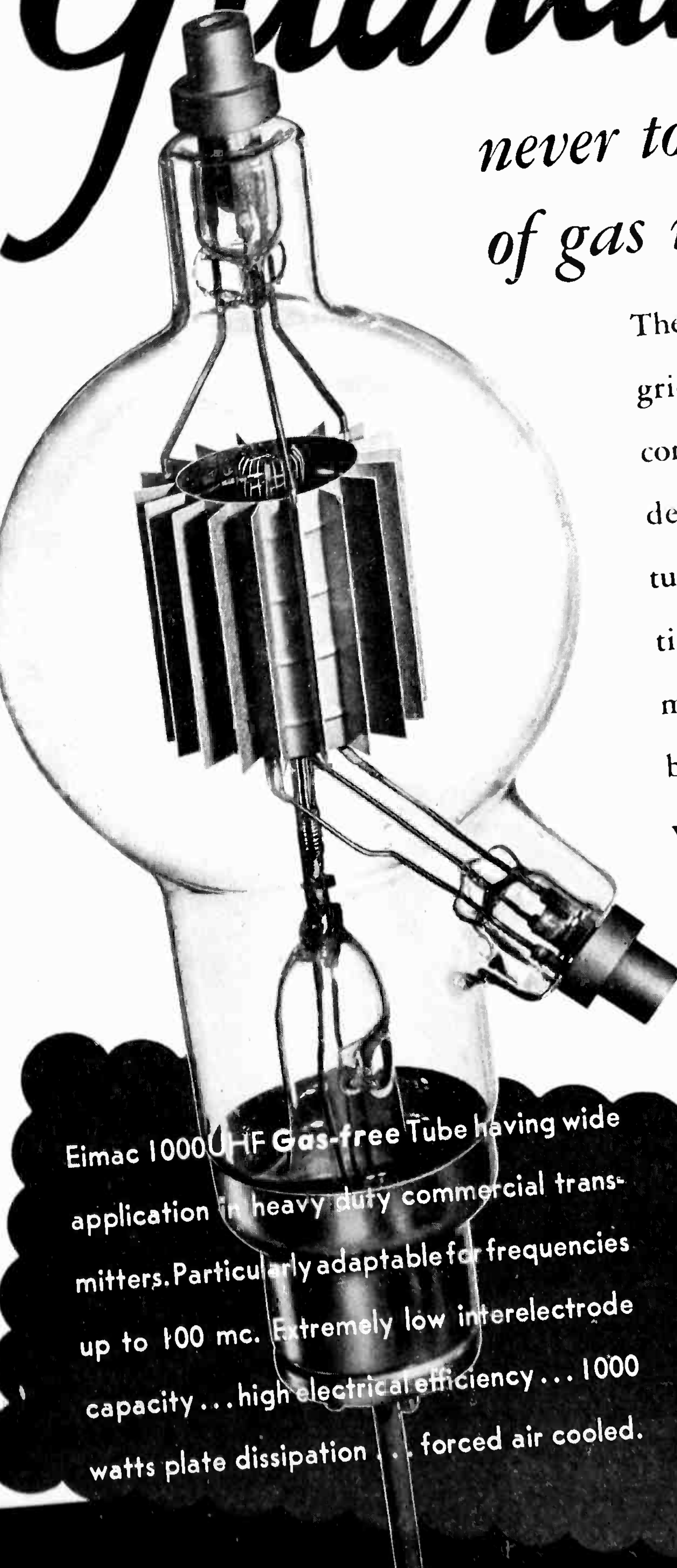

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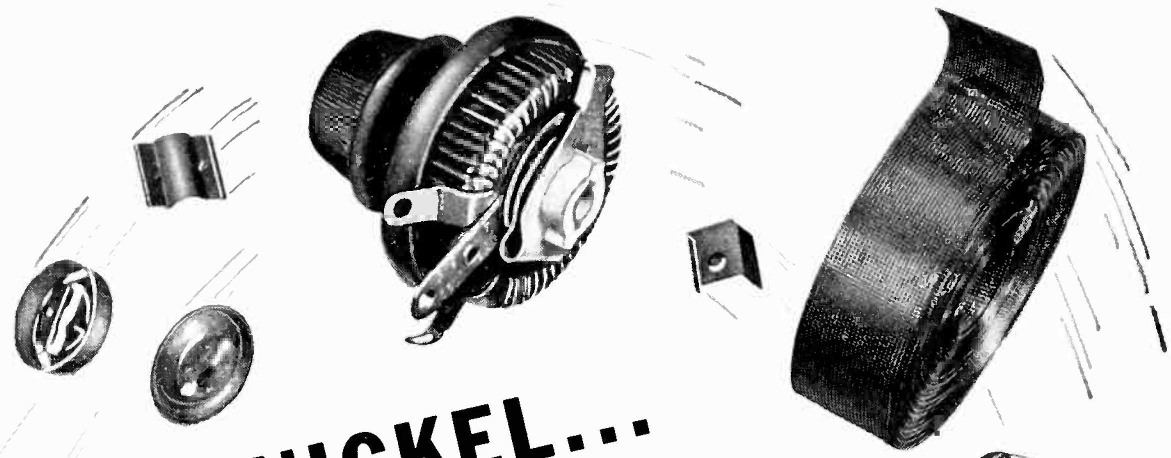

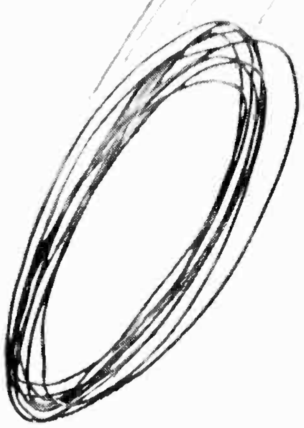

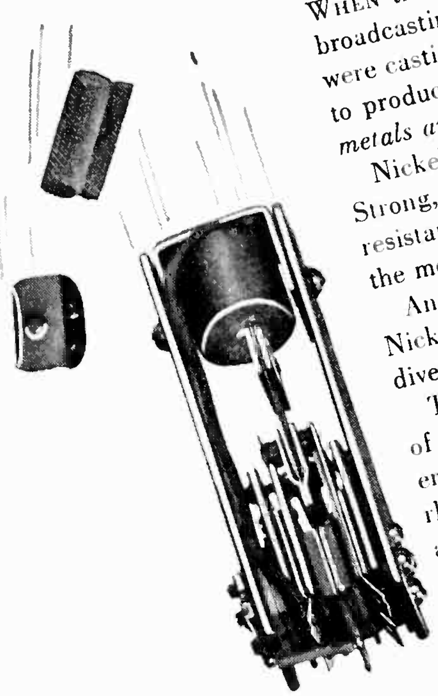

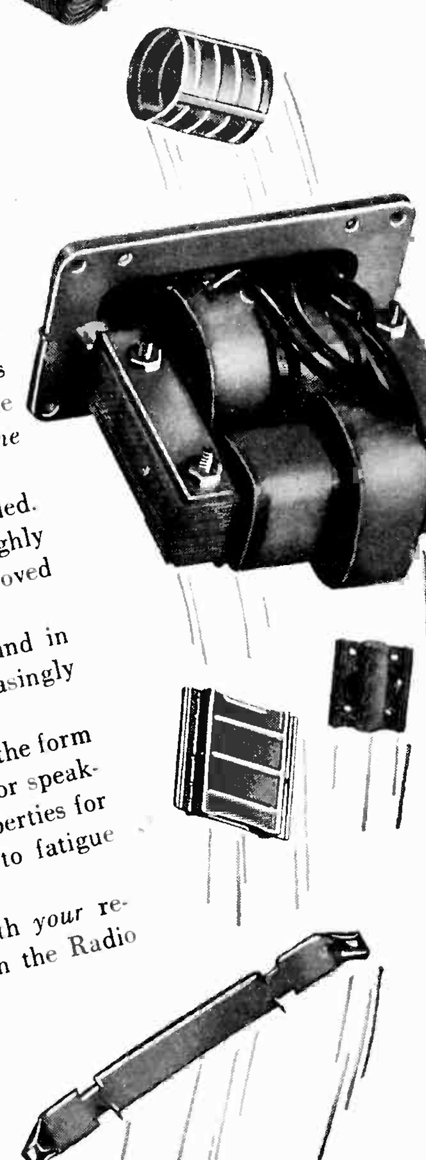

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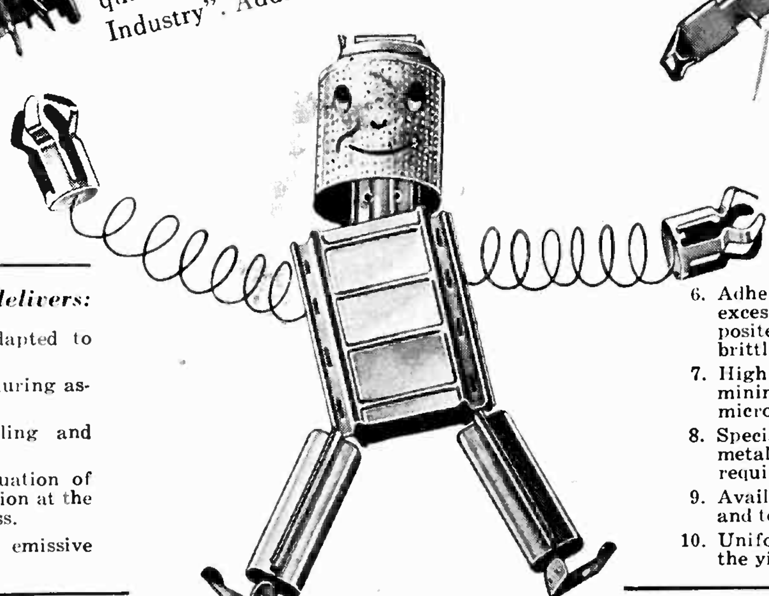

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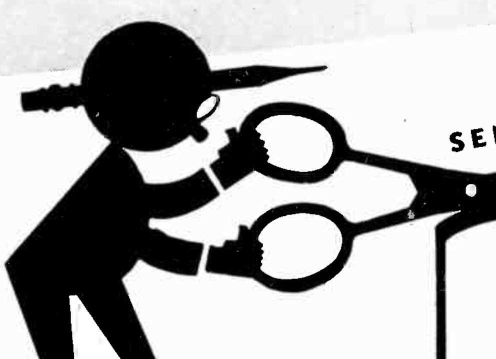

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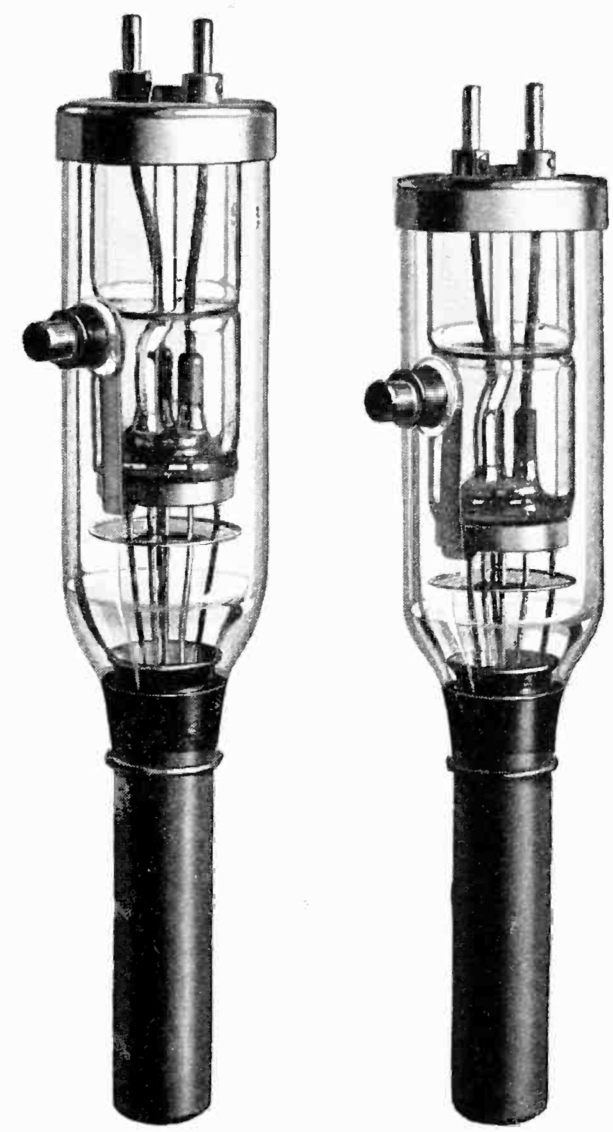

NEW 342A *—developed from the 232A tube of 1927*

NEW 343A *—developed from the 220B tube of 1923*

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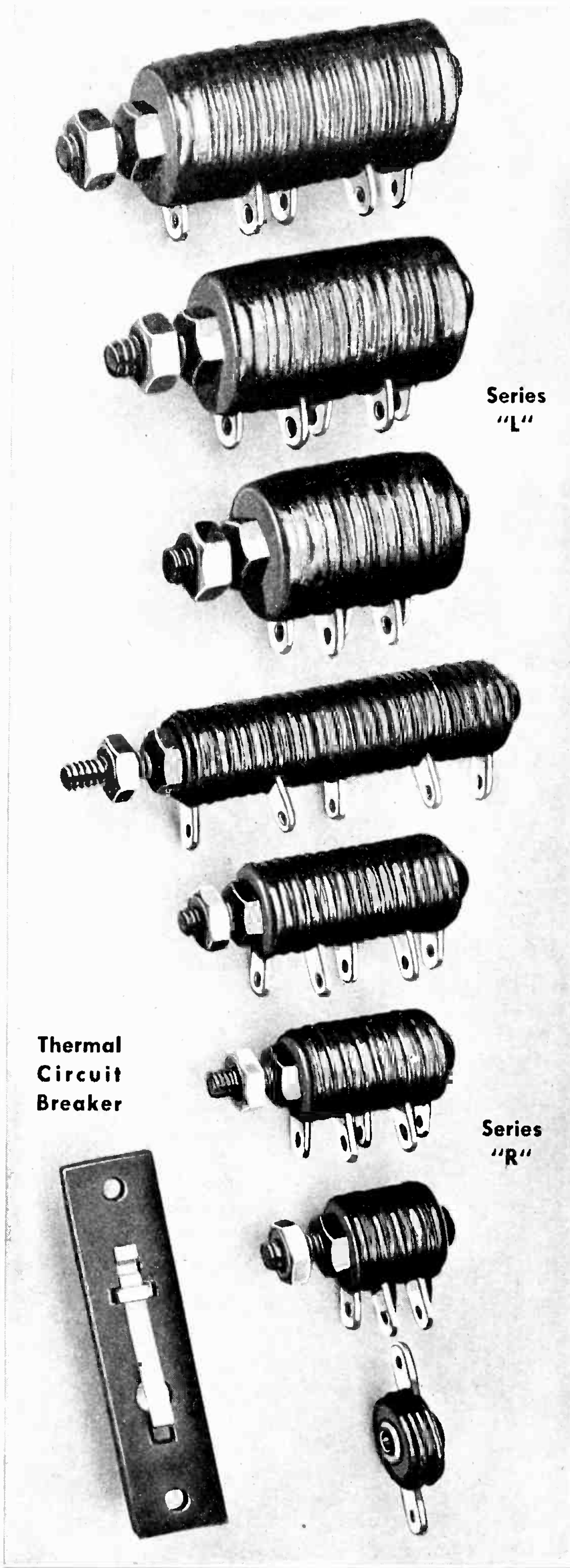

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ELECTRONICS

JANUARY 1939

KEITH HENNEY
Editor

Crosstalk

▶ AVIATION . . . Since Don Fink has been acting as Radio Editor of *Aviation*, a McGraw Hill publication, mighty little on aircraft radio seems to have got its way into *Electronics*. As retribution, therefore, he has prepared a good summary of what has happened recently in this extension of communication sans wires. It is the lead article in this issue. It is interesting to note that the highest radio frequency in use is employed in the Bell Laboratories terrain indicator.

Another sister publication, *Business Week*, has made use of Mr. Fink's technical knowledge. The December 31 issue of this weekly contains another of its exhaustive "reports to business executives," this time on television. The editorial staff of *Business Week* called upon the managing editor of *Electronics* for advice, as well as for a certain amount of typewriter pounding. If you want to know the present status of television see *Business Week*, December 31.

▶ VISITORS . . . During the month, the editors entertained Mr. Sagall of Scophony, London, who was in this country sounding out the interest in large size television images. . . . M. Albert Kaufman, Ferrolyte, Paris, entertained us with his description of how fast the girls at Camden make radio sets compared to his high speed workers in France. He has one of the best looking catalogs of radio parts we have seen, illustrated with his own photos—a work that would do credit to any American catalog. . . . One Dr. Ing. So-and-so of Berlin came in. Grandfather Jewish and murdered; wife and children God knows where in Germany, himself sleeping in Grand Central Station, without food. Well educated, an engineer, an editor, eyeglasses pawned, underclothes thrown away after one night in a flop house—he is hoping for something to do. . . . Radio Gramaphone, Birmingham, writes that our November criticism of the English sets with their push buttons of poor mechanical design, gripes them a bit. "All the push button switches used in this country are assembled from parts imported from the U.S.A."

▶ HOBBIES . . . Dr. C. G. Suits of the General Electric research laboratory recently conducted a survey among G.E. engineers to determine their hobbies. Most interesting have been the results, as published in the *G.E. Review*, November. It seems that the most deserted hobby is radio; 13 out of 60 replies indicating that radio, once a hobby, had been dropped, largely through loss of interest in building receivers. On the other hand, photography was indicated by over half the replies as being an outstanding interest, many doing their own processing.

Knowing of the increasing interest in photography, already at high water mark among radio engineers, leads the editors to wonder if a department on this subject should be added to *Electronics*. It might be difficult to justify, although everything is electronic if you don't care how far back you go into the ultimate constitution of things.

▶ WQXR RADIO . . . For many months many New York City listeners have tuned their radios to WQXR, 1550 kc, and have let 'em ride all evening, listening to recordings of the world's best music. Now the staff of this station, working under the direction of J. V. L. Hogan and Raymond Wilmotte, have designed a high fidelity receiver to be built and distributed by Ansley Radio Corp. There will be no short wave bands, no gadgets, no table models. It is designed for sound; it will respond equally to frequencies between 60 and 7500 cps, but total range is said to be from 20 to 16,000 cps. Other technical data: uniform response to all frequencies over an angle of 150 deg. in front of speaker; operates from a.c. or d.c.; 11 tubes; 12 in. speaker. Purchasers are given one year free service and guarantee on all parts except tubes for 6 months. We hope they have figured their costs correctly because the list price is remarkably low.

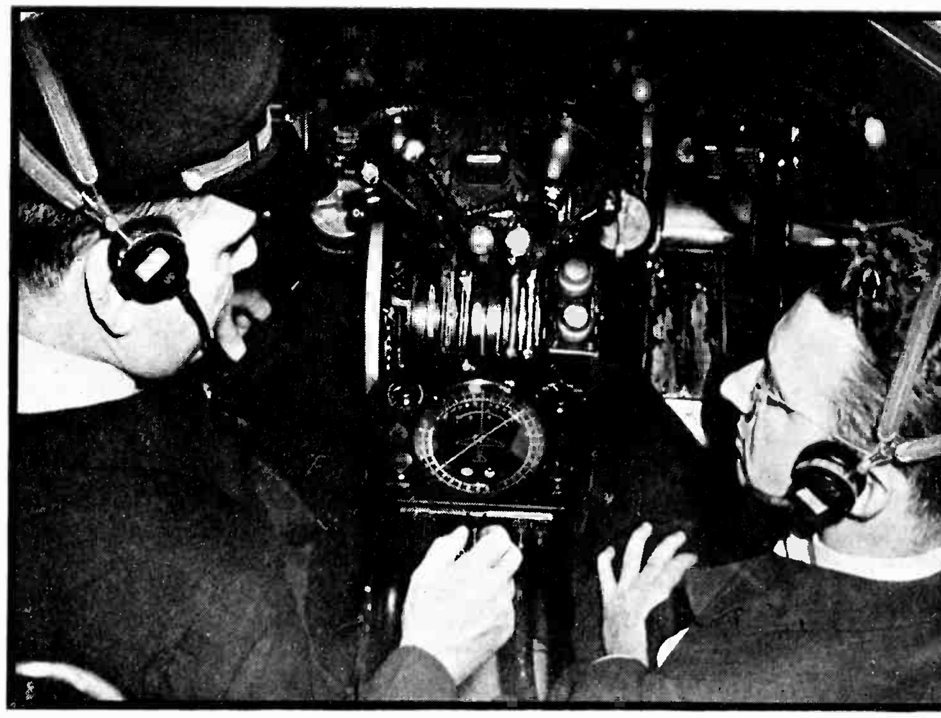
It is reported, furthermore, that L. G. Pacent is developing a high fidelity receiver for the metropolitan market. Ansley, by the way, is building several beautiful models of radio receivers, as well as electronic musical instruments.

▶ GOOD WILL . . . Western Electric plants at Kearney, N. J. and Point Breeze (Baltimore) played open house recently. Nearly 100,000 members of the families and friends of employees of WE saw where telephone cable, switchboards, vacuum tubes, broadcasting equipment, hearing aids etc., were made—and better, where their friends and relatives worked.

"Western" has recently issued the first booklet about itself written in popular style. It is the "Story of Western Electric, Service of Supply for the Bell System." At present writing the Bell System employs about a quarter of a million people handling 85 million telephone conversations each day.

Aircraft Radio, 1939

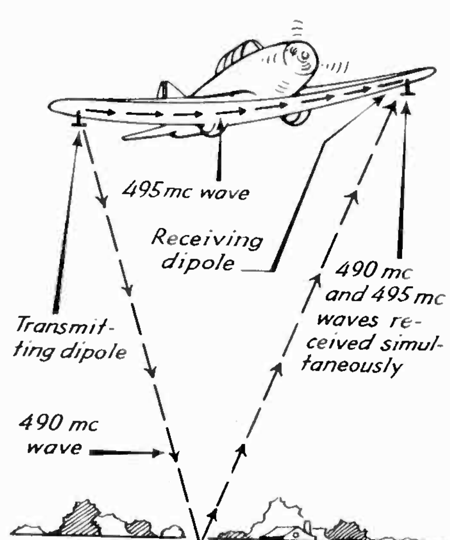
Aviation radio engineers, seeking more dependable radio aids, have applied ultrahigh frequencies to the problems of altimetering, course finding and course marking, blind landing and traffic control. These achievements are reviewed herewith



"Index finger" direction finder. The pointer indicates the direction of the received station, continuously and automatically

THE past year has been more intensive development of aircraft radio services than any period of equal length in the history of aviation. Since our last report on the state of the art (*Electronics*, February 1938, page 20) hardly a month has passed without an announcement of major importance by the airlines, by commercial organizations, or by engineers of the government service. One of them, the absolute altimeter developed jointly by United Airlines and the Bell Laboratories, was featured on the front page of the *New York Times* and hailed as one of the most important aids to safety in the air ever developed. The technical significance of the altimeter is no less important, for it marks the use of the highest frequency yet applied to regular service, 500 Mc.

Another announcement, this time by the staff of M.I.T., disclosed the development of a blind landing system employing frequencies in the hundreds of megacycles, using "horn" radiators of the wave-guide type to establish the landing beam. A cathode ray tube is used as the indicator in this system. The engineering division of the Civil Aeronautics Authority (successors to the Bureau of Air Commerce) has been developing course markers and airport boundary markers operating at 75 Mc, and traffic control and radio range beams at 125 Mc. The same engineers have built a superheterodyne with 5 microvolt sensitivity and a continuous tuning range from 60 to 132 Mc. The



Frequency-modulation system of absolute altitude indication

Sperry Company and the RCA Manufacturing Company jointly announced a radio direction finder, operating on the 350-450 kc beacon band, which is completely automatic in operation, pointing toward the station being received without any attention from the pilot. These applications cannot fail to claim the attention of all engineers interested in radio, whether they have ever flown in an airplane or not. Accordingly the editors prepared this report of some of the technical background of recent developments.

Since flying began, pilots have had but one quantitative indication of their height above ground, that is barometric pressure. Barometric pressure serves to indicate height above sea level, and is subject to variations with the weather. Consequently it is necessary to inform the pilot of changes in barometric pressure arising from the latter cause (one of the principal uses of radio communication) and in addition the pilot must know how far above sea level the ground under him happens to extend. If the pilot is lost under conditions of poor visibility, therefore, he may easily fly into the side of a mountain, with his altimeter indicating a safe altitude in terms of height above sea level. The moral is, don't get lost.

An altimeter was obviously required to indicate height above the ground. Such an altimeter (called "terrain clearance indicator") came into being at the hands of the engineers of the United Airlines and the Bell Telephone Laboratories, and was demonstrated for the first time in October. The demonstration plane was fitted with two tiny dipole antennas, one for reception and the other for transmission, mounted under either wing. The transmitting dipole (about 12 inches long and separated 6 inches from the metal surface of the wing) is fed with about 5 watts at 500 Mc. The wave, directed to the ground, is reflected therefrom and received by the receiving dipole. At the same time the receiving dipole receives some energy directly from the transmitting dipole opposite. Thus the receiving antenna intercepts two signals, one an "underwing" signal, the other a "reflected" signal. If the two signals can be caused to interfere with each other, the interference may be used to indicate the time of reflection, between transmission and reception. This time, multiplied by the velocity of the wave, gives the distance of reflection, which is twice the altitude of the plane.

To date no definite statement of the manner of causing the interference between the reflected and underwing signals has been made by the organizations involved, but one very plausible explanation is as follows: the transmitting dipole may be fed a frequency modulated signal, such that the increase and decrease of frequency are linear with respect to time. Suppose then that the rate of change of frequency is sufficiently rapid that it can change its value appreciably within the time of reflection of the reflected wave. Then the receiving dipole will receive two signals differing in frequency, the underwing signal having a frequency equal to that sent out at the instant under consideration, while the ground-reflected wave has a frequency equal to that sent out when the reflected wave left the transmitter. The frequency difference between these two waves is, then, proportional to the reflection time, which in turn is proportional to the reflection distance. The two signals are amplified, and passed through a detector, in the output of which appears a frequency equal to the frequency difference. This output signal is measured on a direct-reading frequency meter whose dial is calibrated directly in feet. The accompanying illustration indicates the situation when the reflected wave has the frequency of 490 Mc, and arrives at the receiver by the time the frequency of the underwing signal has shifted to 495 Mc, which is transmitted directly under the wing. The difference, 5 Mc, is proportional to the altitude.

In practice the altimeter will indicate heights from a minimum of 20 feet to a maximum of about 4000 feet, the latter limit being determined by the available transmitter power. The dynamic response of the indicator is very rapid. In the demonstration when the plane passed over the George Washington Bridge, proceeding north along the Hudson River, the indicator jumped down (indicating lower terrain clearance) momentarily while passing over the bridge.

The utilization of the ultra high frequency of 500 Mc is based on three important factors: the high degree of directivity obtainable with simple antenna structures; the high degree of reflection from any solid or liquid surface, regardless of electrical characteristics; and the large changes in absolute frequency which may be obtained from small percentage changes in the frequency-determining source.

Traffic control. An inside view of the control tower at Newark Airport. The operator controls the flying and landing of all planes in the vicinity

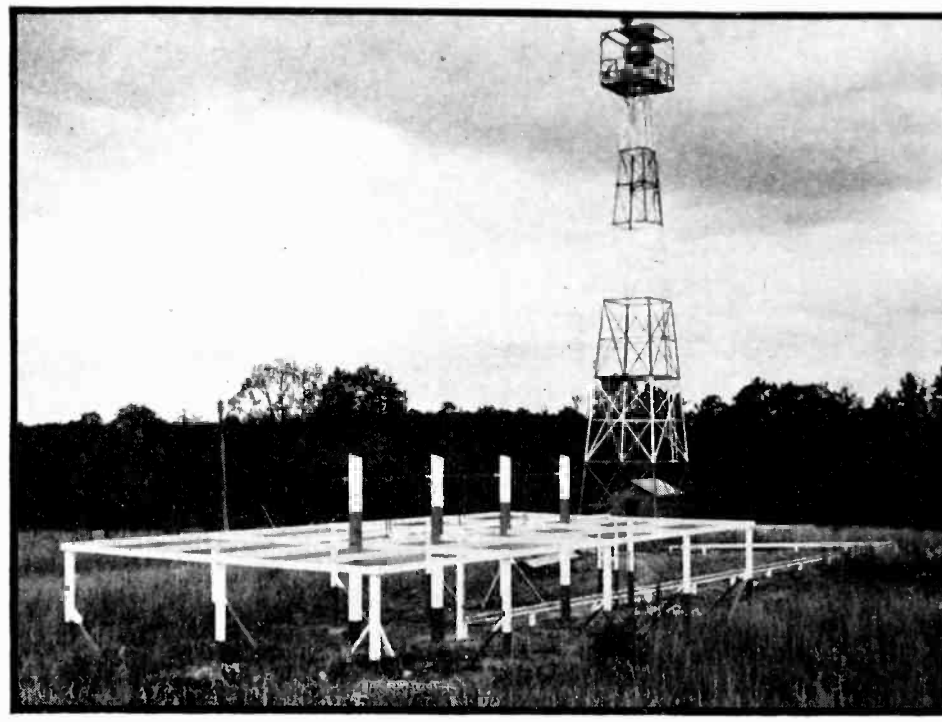
A Station-Seeking Radio Direction Finder

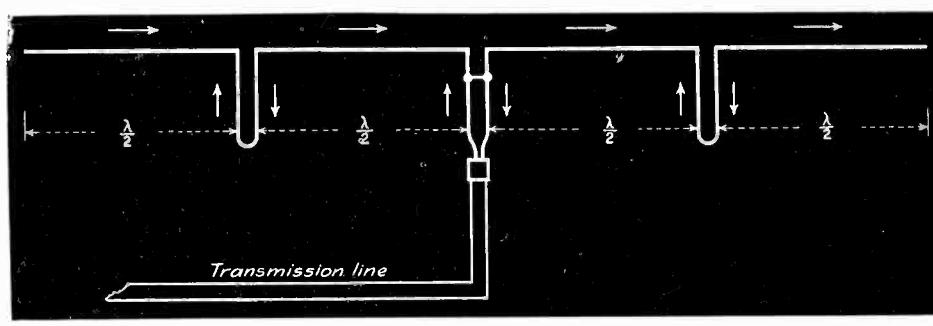
Loop direction-finders for aircraft have been in vogue for several years (they are required equipment on air-line ships), but they reached the peak of effectiveness only recently, when they were made completely automatic by engineers of the Sperry Gyroscope Company, working with a compass especially designed for the purpose by the RCA Manufacturing Co. The visual-indicator compass we

The two dials show the altitude indications of a barometer-type meter (left) and u-h-f reflection-type indicator. With only 100 feet actual clearance, the barometer shows 800 feet altitude above sea level

recall (see *Electronics*, October 1935, page 6) makes use of two antennas, a loop and a straight wire. The voltage induced in the loop antenna is amplified and mixed in a balanced modulator with locally-generated 90-cycle a.c. The output of the modulator contains 90-cycle sidebands whose phase reverses as the loop passes through the null-point (when the plane of the loop and the plane of the wavefront coincide). The modulator output is mixed with the signal received from the straight wire antenna, with the result that the 90-cycle component in the output has a polarity dependent on the direction of the loop with respect to the incoming wave. If the loop is directly on the null, no 90-cycle component is received. If the wave comes from the right, the 90-cycle component is present and has one polarity. If the wave comes from the left, the component is present, but with the opposite polarity.

In the new system, the 90-cycle component is filtered out of the receiver output and is applied to an electronic control circuit which drives a reversible motor. The motor is geared directly to the shaft of the rotatable loop. The phasing of the motor connections is such that if the signal is to the left, the motor tends to drive the loop to the left; when the signal is to the right, the motor reverses and drives the loop to the right. The motor power is derived ultimately from the 90-cycle component, which disappears when the loop reaches the null position. Consequently the motor tends to drive the loop in the direction of the null position. Whereupon, on reaching the null position, the 90-cycle component disappears and the motor stops, leaving the loop on the null. If the plane veers from its course, either to the left or the right, the motor again comes into play, driving the loop to the null position. In this manner the loop is always constrained to take a position at right angles to the direction from which the signal is coming. A pointer, attached to the loop by a flexible shaft, indicates the position of the loop to the pilot, who is thereby apprised at all times of the direction to the station to which he is listening. He tunes in a station, the loop and its attached pointer immediately swing in the direction of the station, and hold that position regardless of the direction of flight or maneuvers of the plane. The Sperry engineers who designed the follow-up circuit, have carefully removed any tendency to hunt, so the pointer takes up the null position without overshooting. There are two nulls in the loop rotation, of course, but only one of these is in stable equilibrium, since the loop tends to move away from the other. Consequently the 180° ambiguity of simple loop systems is avoided and the pointer is fitted with an arrow head which points directly to the source of the signal. When the plane flies directly over the station to which it is tuned, the pointer reverses itself, giving a definite indication that the station has been passed and thereby fixing the position of the plane. The device requires no attention from the pilot, except tuning and an occasional glance at the pointer to note the direction or change of direction of the station.





The fan-type marker beacon at Bowie, Maryland, which sends a "fan" of 75 Mc signal vertically upward, across the path of the low frequency radio beam. Below, the method of producing in-phase currents in four half-wave segments, from which the "fan" is radiated

Blind Landing—A New Approach

The landing of airplanes by instruments (blind landing) is an art which has progressed until lately along one path. That path was originally surveyed by the Bureau of Standards, who devised a system of blind landing based on the fact that a locus of constant signal strength may be set up over an airport by projecting a beam-like signal across the landing area. Part of the signal is reflected from the ground, the rest transmitted directly. The wave-interference between the two components is such as to produce a locus of constant signal strength which extends from a height of a few thousand feet downward to the airport surface. To use this locus as a glide-path for landing, it is only necessary to provide the pilot with a receiver of constant sensitivity, together with an output meter which indicates the desired signal level existing in the locus. By keeping the indicator at one level, the pilot can follow the locus of constant signal, and thus be assured of maintaining the proper loss of altitude. The directivity in the horizontal plane, equally essential, is provided by an

A-N interlocked signal arrangement which actuates a left-right pointer associated with the output meter. Much progress has been made with this basic system, but it suffers from several drawbacks: the glide path is not a straight line, but a curve which necessitates either a change in glide angle, or a change in speed, as the plane nears the earth; the actual position of the locus depends on the conditions of the airport surface, and can be seriously altered by the presence of snow; finally the apparent position of the locus depends on the receiver sensitivity which may change without the pilot's knowledge.

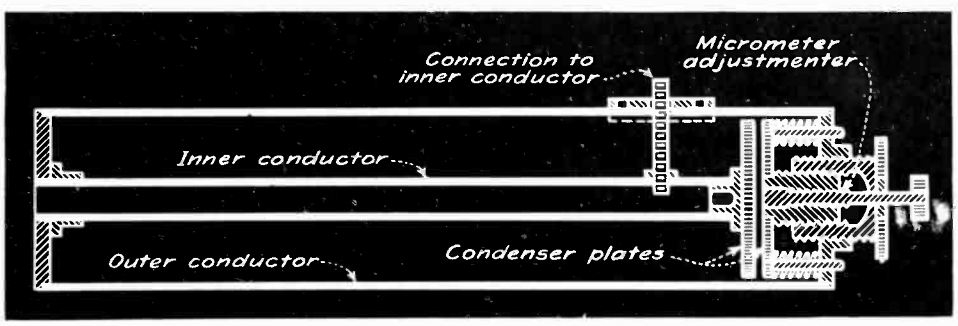
In September, members of the staffs of the Electrical Engineering and Aeronautical Engineering Departments at M.I.T. released information on a blind landing system which may overcome all these defects. The system is still under development, and has not yet been tested under flight conditions, but it seems to have considerable technical merit. The landing path is produced by employing four beams, each beam being in the shape of a thin, wide "pancake". Two such pancake beams are produced with their planes nearly horizontal and inclined to the surface of the airport. They are modulated with differing audio frequency tones, and are detected by a receiver containing filters which separate the tones and cause them to actuate signal lights. The two beams are so placed that they overlap slightly. If both signal lamps light, the pilot knows he is in the boundary between the two beams. If the upper light lights, he knows he is above the overlap region; if the lower light lights, he is below it. The pilot's task is to keep the plane in the overlap region and thereby to follow the incline of the overlapping plane to the airport surface. The path he takes is a straight line, since the region of overlap is a flat plane.

Similarly two pancake beams with their planes vertical are overlapped and identified by different audio tones and signal lights. The intersection of the two overlapping regions forms a glide path, in the form of a straight line, which the pilot may follow directly to the airport surface. The four signal lights show him whether he is above, below, to the right or to the left of the landing path.

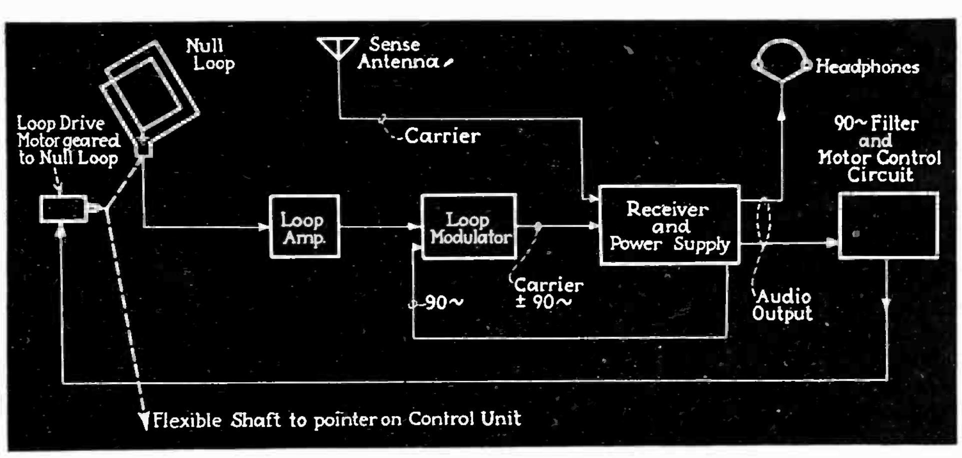
The beams are formed by a new technique, discovered independently by Dr. W. L. Barrow of M.I.T. and Dr. G. C. Southworth of the Bell Laboratories. By employing very short waves (less than one meter in length) it is possible to project beams of almost any desired shape by projecting them from the mouths of horns or "wave-guides" in much the same manner as sound is projected from horns, but with a much more definitely confined beam. By employing a horn whose width is great compared with its height, a beam may be formed whose height is very great compared with its width (one of the vertical beams referred to above). The shape of the beams depends only on the shape of the horn structure relative to the wavelength employed, and is independent of conditions on the ground surface. Waves of frequencies from 200 to 600 Mc have been experimented with to determine the truth of the theory and have shown that beams of the required shape can be produced and maintained. Receivers for the hundred-megacycle waves have been developed, employing crystal-controlled oscillators and wide bandpass i-f circuits. Receiver sensitivity may vary without affecting the indications, so long as any indication whatever is given. Nor is the value of receiver sensitivity necessarily high, since the beams conserve the transmitter power.

The manner of indicating the position of the ship, relative to the landing path, has received a great deal of consideration. The original idea behind the development arose in the mind of Irving Metcalf of the Bureau of Air Commerce. He visualized three transmitters, one at the surface of the airport, two suspended on either side of the run-way, and all three received by the pilot in such a way that he could "place" the position of each transmitter as if they were three beacon lights he could see. By keeping the three beacons in a straight line, the center one midway between the other two, the pilot was assured of being on a straight line landing path and of descending at the proper angle for easy landing.

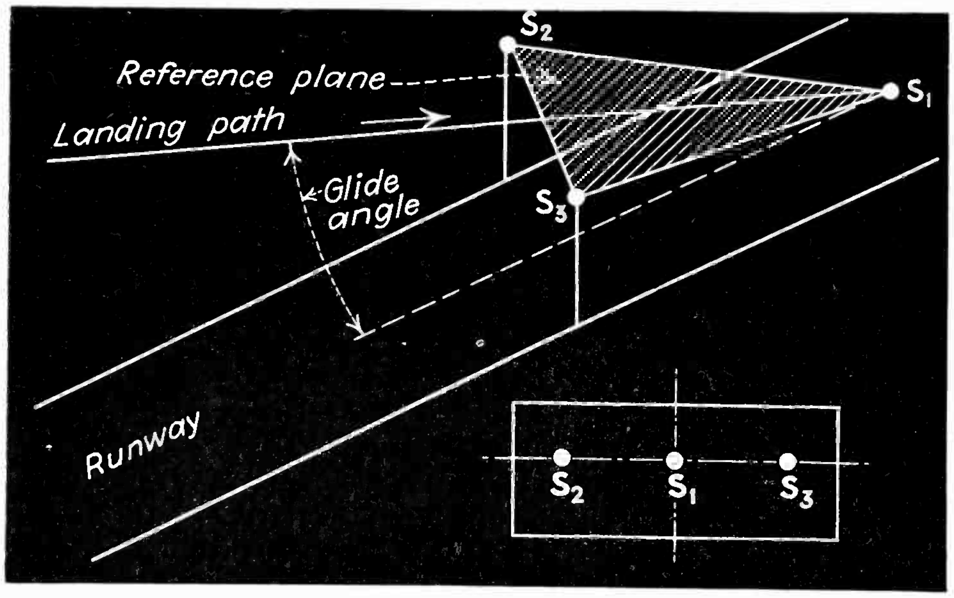
The Metcalf idea has been applied by setting up a cathode-ray tube as the indicator, and by producing three spots on its screen in such rapid succession that the eye appears to see them all at once. The spots are formed by commutating voltages applied to the deflecting plates and control grid of the tube. The center spot is controlled by voltage derived from the four beams previously described. It



Concentric tuned circuit employed in 60–132 Mc receiver designed by engineers of the Civil Aeronautics Authority. The assembly is eight inches long, and is tuned by a micrometer screw



Block diagram of the Sperry-RCA automatic direction finder. By coupling the receiver output to a motor which rotates the loop, the null position is maintained automatically



The "three-light" (S_1, S_2, S_3) system of blind landing, originally proposed by Metcalf of the CAA and developed at M.I.T. The three spots are indicated on the surface of a cathode ray tube

takes a position above, below, left or right of center, depending on whether the plane was above, below, left or right of the glide path.

The outer two spots are controlled by voltage obtained, not from two other transmitters, but from navigation instruments already available in the plane, the gyroscope compass and the gyroscope artificial horizon. The connection between the gyro instruments and the electrical indicating circuits is made by mounting a voltage divider within the case of each gyro. The divider consists of a resistance wire wound on a curved card, against which rides a fine tungsten catswhisker which is fastened to the gyro element. In the case of the gyro compass, a direct voltage is applied to the resistance winding, and the portion picked off by the catswhisker is applied to control the horizontal deflection of the indicator. In this way, the outer two spots of the three spot system are shifted bodily to the left or right, depending on the motion of the gyro compass element. In the case of the artificial horizon, an alternating voltage is applied to the voltage divider, and this alternating voltage is applied through the commutator to the vertical deflection plates. The alternating voltages causes the line between the outer two spots to incline at an angle corresponding to the angle indicated by the artificial horizon.

The indication of the gyro compass and the gyro horizon on the cathode-ray screen is merely a convenience, since the gyro instruments are mounted on the instrument panel of the ship. But the consolidation of these indications is very important from the pilot's point of view, since he is thereby required to watch but one indicator, rather than three.

In making a landing, using the cathode ray indicator, the pilot sees to it first that he is on the landing path, as indicated by the position of the center spot. Then he maintains the center spot centrally between the outer two spots, indicating the proper direction as determined by the gyro compass. Finally he maintains all three spots in a straight level line, thereby assuring himself that his wings are on even keel. He then descends at landing speed until his wheels touch the surface of the airport.

Civil Aeronautics Authority Engineering Projects

At the end of 1937, the FCC announced a new allocation of ultra-high frequencies in which was included several new assignments for aircraft use. Among the most important of these frequencies are those in the neighborhood of 75 Mc, applied to marker beacons along the airways, and those at 125 Mc (126.54 to 131.84 Mc), reserved for airport traffic control.

One of the problems associated with the development of these services is the design of a suitable high-sensitivity receiver. A superheterodyne receiver with a continuous tuning range from 60 to 132 Mc, with 5.5 microvolt sensitivity and with such stability that it holds its tuning within 100 kc in 100 Mc, has been constructed by engineers of the Civil Aeronautics Authority. The tube line-up is a 954 acorn tube for r.f., a 954 converter, a 955 oscillator, two 6K7 i-f stages operating at 5.5 Mc with 200 kc bandwidth, a 6Q7 second detector and a.f., and a 41 output tube. The secret of the receiver is the method of tuning. Ordinary coil-and-condenser tuned circuits are not suitable since their Q is low and decreases at the highest frequencies. Instead, coaxial circuits, illustrated in the accompanying figure, are used in the r-f, converter and oscillator sections. Tuning is accomplished by a micrometer screw which varies the capacitance between plates contained within the coaxial shield. The choice of base metal and coating metal was carefully investigated to produce a minimum of detuning with temperature changes and to insure high Q. The coaxial circuits are about 8 inches in length and rather heavier than coil and condenser circuits but their superior performance justifies their use.

Fixed tuned u-h-f receivers for use in regular airline service have been developed commercially. One of the first to be announced, the Western Electric 27A, is a six-tube 75 Mc receiver, equipped with a lamp control which responds individually to audio modulations of 3000, 1300, and 400 cps. The oscillator is crystal controlled, and produces an intermediate frequency of 6.325 Mc. The sensitivity is such that the control operates on an input signal of 150 microvolts, 30 per cent modulated. The audio output is 150 milliwatts with the same input.

The 75 Mc receivers are intended for use as marker-beacon indicators. Three types of beacon are now in development, all operating on 75 Mc: (1) a fan-type marker which sets up a broad, thin vertical wedge of signal, with its plane at right angles to the airline route; (2) a cone-of-silence marker which sends a vertical cone of signal to mark the location of radio-range beacons; and (3) airport-boundary markers which send up fan signals over the edges of airport areas.

An excellent illustration of the progress made in u-h-f beacons is the installation made by the CAA at Bowie, Md. The transmitter is crystal-controlled, and develops 100 watts

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Initial Drift in Photocells

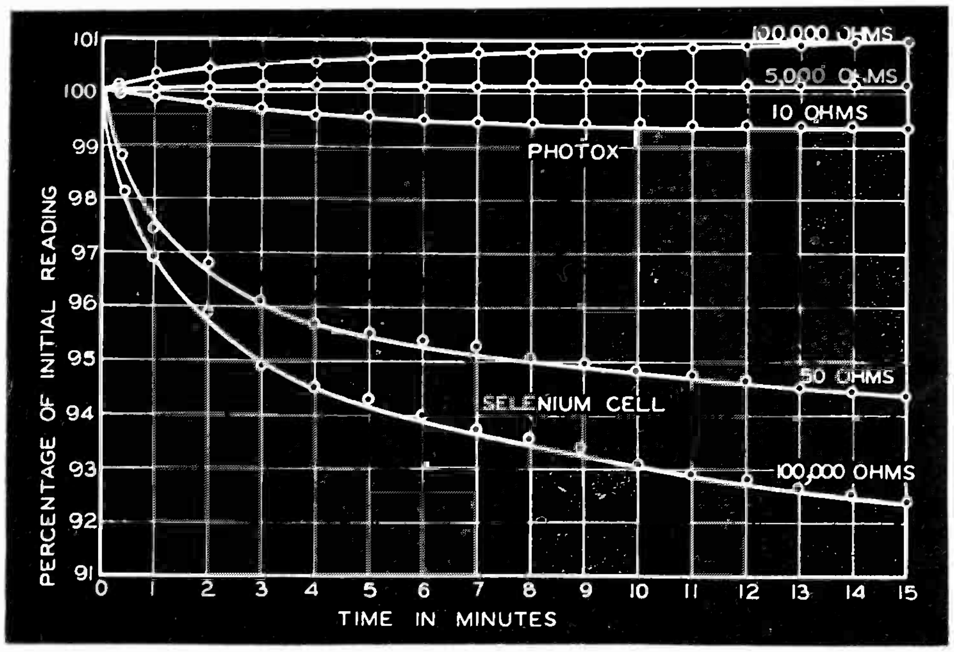
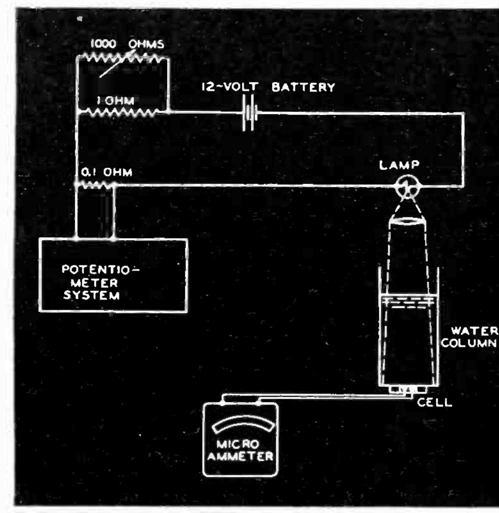


Fig. 2—Initial drift of Photox cells at 50 foot-candles compared to that of a selenium cell

Fig. 1—Schematic diagram of apparatus used to determine initial drift of photocells



By E. D. WILSON

Research Laboratories
Westinghouse Electric and Manufacturing Co.

THERE seems to be general confusion among engineers in the interpretation of the term fatigue as applied to the behavior of photovoltaic cells. While the word is usually intended to describe a transient drifting of current when a cell is suddenly exposed to light, it has also been employed to designate the gradual depreciation in sensitivity over periods of months, which is characteristic of some cells. The writer is inclined to agree with Elvegard and others[1] in calling the former phenomenon, which endures only a few minutes and is completely reversible, simply an initial drift. If a cell loses sensitivity with time, it may be said to age or depreciate.

The word photocell was formerly applied[2] to any type of photo-electric element, but since the motion picture industry has generally adopted the name phototube for the emissive type, there has been a trend to use photocell specifically for the voltaic type. This has much in its favor, and, after all, common usage is the determining factor in the final christening of common articles.

For convenience, circuits involving photocells may be grouped into two great classes: (1) those requiring relative permanency of calibration, such as light meters and exposure meters; and (2) those requiring relative freedom from initial drift, such as transparency meters and comparison devices. In the second class, it is common practice to compare some optical property of a given material with that of an established standard. The comparison is to be made with considerable precision and hence any appreciable drift in the cell between readings is intolerable. However, because the cell may be standardized as frequently as the operator desires, any long-time depreciation is utterly negligible. It is important, therefore, in selecting a suitable cell for a given circuit, to consider which characteristic is of most importance to the measurements in question.

It is the purpose of this paper to record some carefully conducted measurements on the initial drift of copper-oxide Photox photocells. While the Photox is recognized as not being completely permanent, having an expected average depreciation of about one per cent per month, and is not generally recommended for permanently calibrated units, nevertheless, it does have several characteristics of considerable interest to designers of light-sensitive circuits. Among these characteristics is its relative freedom from initial drift.

Because there are many parameters which might be changed to obtain an endless array of data, it was decided to restrict the measurements to one typical intensity of illumination, 50 foot-candles; one temperature, approximately 27°C; and to one spectral distribution, tungsten radiation at about 2550°K. Actual observations were made on current outputs of each of five typical cells into loads of 10 ohms, 5000 ohms and 100,000 ohms. Similar measurements were also made on selenium cells.

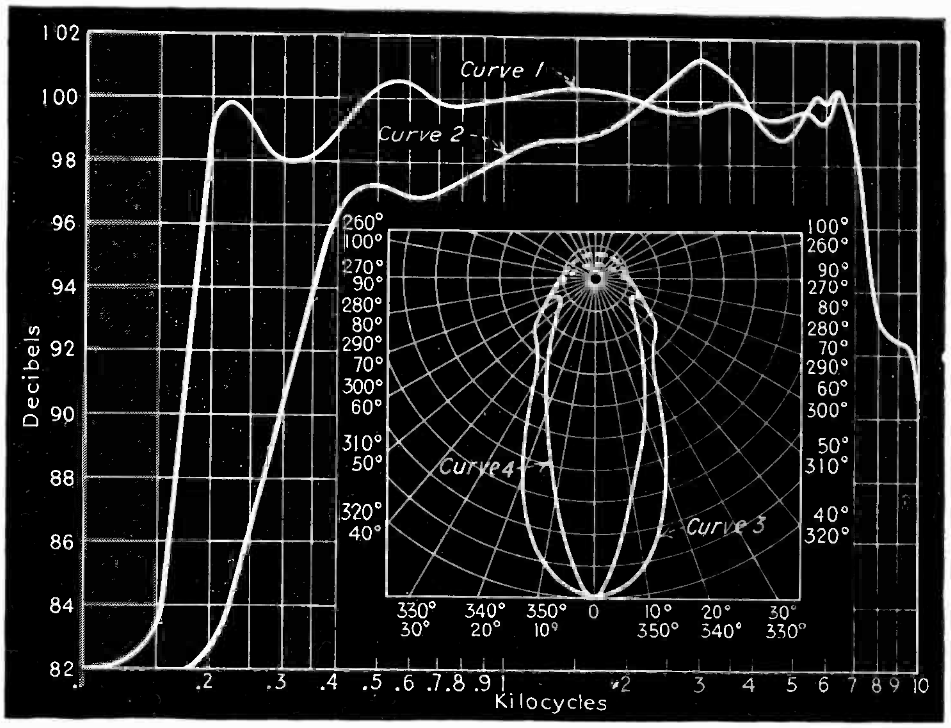
To make the readings of cell current significant, precautions were taken to maintain the intensity of light constant within 0.1 per cent, and to minimize any possible change in temperature of the cell. Lamp current was supplied from two 6-volt storage batteries in series. The main current flowed through a standard resistance of 0.1 ohm value and also a fixed resistance of one ohm value across which a smoothly variable 1000-ohm resistor was paralleled as indicated in Fig. 1. A potentiometer across the standard resistance was capable of indicating the voltage drop to three- thousandths of one per cent. Counting the visible radiation as

[Continued on page 33]

[1] E. Elvegard, et al., *J.O.S.A.*, 28, 33, 1938.
[2] Zworykin and Wilson, "Photocells and their Application."

CONCENTRIC FOLDED

By A. J. SANIAL
Chief Engineer, Guided Radio Corp. New York, N. Y.



Curve 1—Driver coupled to straight trumpet
Curve 2—Driver working into a folded horn
Curve 3—Trumpet with mouth diameter of 2 feet
Curve 4—Folded horn with same mouth diameter

In spite of the benefits accruing from the use of horns to load loudspeaker units, the straight exponential trumpet is today proving too bulky and cumbersome compared to dynamic cone and baffle loudspeakers. Among the things which have been sacrificed in abandoning the exponential horn and driver loudspeaker are higher efficiency and smoother response over a wide range together with the ability of controlling the directional charactertistic.

However, it is not necessary to tolerate the long, space-wasting straight horn in order to gain its advantages. The horn may be folded in any number of different ways. A popular method in use is to curl the horn up like a snail shell or back and forth on itself or in dozens of combinations of these methods. Most of these horns have the bad fault of having vastly different path lengths along the two curved walls from the throat out to the mouth, and this results in serious cancellation of frequencies, especially at the high end. There are some which keep the path lengths more nearly equal and the radii of the bends large compared to the sectional width of the horn at the bends, by expanding the horn section rapidly in a direction normal to the bends. Folding the horn back and forth on itself concentrically is a more attractive method. It results in a symmetrical structure throughout, a longer air column can be obtained in a given volume without sacrificing other properties, it is practically impossible for water to reach the throat, unless the whole is completely submerged in a certain way, and most of the ordinary dust and dirt is automatically kept out, and it can be manufactured of metal much more cheaply than other types of folded horns. In addition, practically no panel resonance is encountered. If the folding is done correctly and carefully, its performance will be quite as acceptable, and it will occupy but a fraction of the space it took up as a trumpet. The toll exacted for this saving is 1) somewhat greater cost than a trumpet, 2) an added loss at the higher frequencies. The cost can be regulated by the actual mechanical design and the method of fabrication used, while the high frequency loss can be kept low by attention to fundamental acoustic principles in the air column design.

The accompanying curves show the effect of a short folded horn compared to a straight trumpet. Curve 1 is that of a driver unit coupled to the straight trumpet, and in curve 2 the same driver is working into a folded horn with the same throat and mouth diameter as the trumpet. Even though the cutoff of the folded horn is about one hundred cycles higher than that of the trumpet due to a shorter air column, it can be seen that a decrease in the low frequency efficiency due to this fact is about the only major difference in the two response curves. There is a slight tendency in the folded horn to introduce a peak around 3000 cycles.

The directional characteristic is amenable to considerable control by varying the configuration and dimensions of the mouth and the last section of the folded horn. The larger the mouth of the horn, the more directive is its effect at lower frequencies. The directive properties of a ring-shaped radiator can be utilized much more readily with the concentric folded horn due to its inherent construction, and really accounts for the marked beam-like operation of even small size horns of this type. The directional curves 3 and 4 show how sharp the beam of a concentric folded horn can be made. Curve 3 is that of a trumpet type with a mouth diameter of approximately 2 feet, while curve 4 is that of a folded horn of the same overall mouth diameter, both taken at 100 cycles. These curves are plotted to the same scale. Actually other things being equal, the pressure at zero degrees is much greater on the folded horn than on the trumpet. It is of course possible to design a trumpet type horn in the form of a ring radiator but this results in a more complicated and expensive structure. In a horn of this type

HORN DESIGN

which the writer designed, the acoustic pressure on the axis in the 1000 cycle region was increased more than 50% by the insertion of a carefully designed "blob" in the mouth of the horn, compared to the pressure from the original horn at the same frequency. Fig. 1 shows one method (not to scale) of designing a ring radiator type trumpet, which will sharpen the directional curve. All cross sectional areas must be kept in the usual exponential relationship of course, even though annular-shaped.

In designing a concentric folded horn, the standard exponential horn formulas are used to determine the cross sectional areas of the air column at various distances from the throat. These may already be available from an existing trumpet design which it is desired to fold up. If not, dimensions of a straight horn suitable for the requirements should be designed first, from the formula

$$L = \frac{4.6}{m} \text{Log}_{10} \frac{(D_L)}{(D_T)}$$

Where L = Distance of section from throat
D_L = Diameter of section at L
D_T = Diameter of throat
m = Taper determined by lower cutoff frequency

The diameter of the throat D_T is determined by the impedance desired at the throat end of the horn, or if a driver unit is already available this fixes the throat diameter, as there must not be abrupt changes in the horn section. Most of the routine computations involved in obtaining the horn dimensions from the above equation can be eliminated by using the simple graphical methods described in a recent paper by the writer*.

The straight horn, Fig. 2, is now roughly divided into the number of sections into which it is necessary to fold it to meet space requirements specified. Assuming there are to be three folds, a form as in Fig. 3 results. The first section is of course identical with the trumpet for the same length. Just ahead of where the first turn begins the outside of the first section is arbitrarily expanded at a greater rate up to the point of curvature. To keep the air column exponential, a blob just naturally appears in the center of the expanded section when the calculations are made. This can be seen from the section of the horn at this point Fig. 4. The sectional area must be the same as that of the trumpet at this distance, yet the outside diameter a_L is greater than D_L. The diameter of the blob b_L, is then

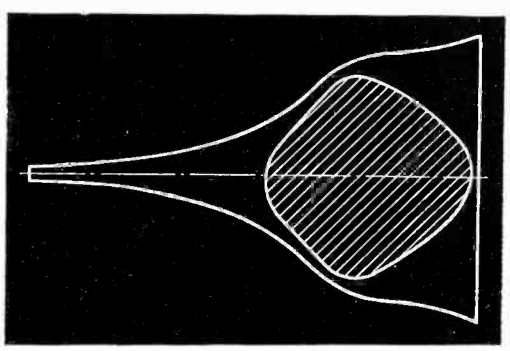


Fig. 1—Section of a ring radiator type trumpet

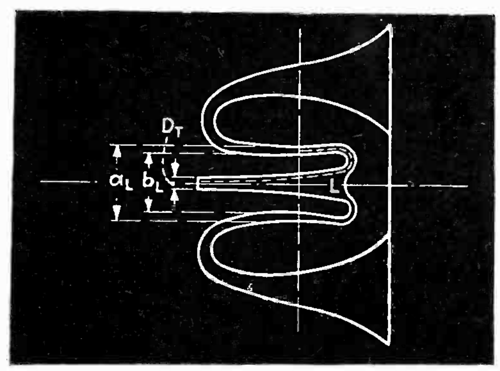


Fig. 3—Resultant horn of three folds

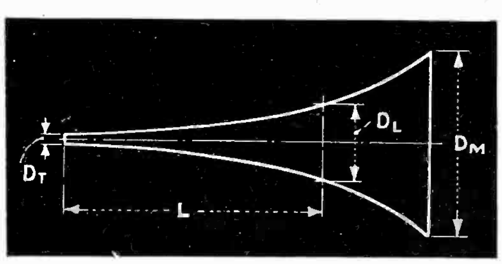


Fig. 2—Design diagram for folded horn

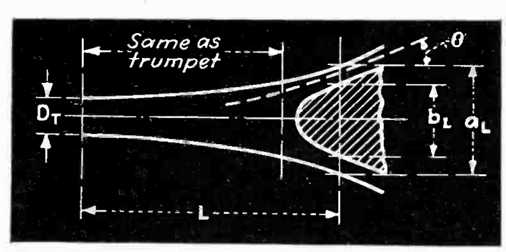


Fig. 4—Design data for blob in horn

$$b_L = \sqrt{a_L^2 - D_L^2}$$

assuming the center line is horizontal or nearly so. If the angle θ from horizontal is appreciable however, the actual horn section is not a plane annulus but is the surface of a truncated cone, the expression of this being

$$A_C = \pi\left(\frac{a_L + b_L}{2}\right)\sqrt{\frac{(a_L - b_L)^2}{4 \tan^2\theta} + \frac{(a_L - b_L)^2}{4}}$$

Equating this to the area of the equivalent trumpet at the same length of air column,

$$\frac{\pi D_L^2}{4} = A_T$$

From which $D_L = \sqrt{\frac{1}{\sin\theta}(a_L^2 - b_L^2)}$

Or $\qquad b_L = \sqrt{a_L^2 - D_L^2 \sin\theta}$

Note that if the outer wall expands rapidly enough, due to the increase in a_L the difference between a_L and b_L becomes smaller. In other words, the section becomes thin which is just what is desired at the point of curvature. This keeps the path length of the sound wave nearly equal on the inside and outside walls of the section as the turn of the horn is negotiated for a given radius of curvature. It is usually found necessary to try various rates of expansion of the outer wall until the section is thin enough so that the difference in path lengths along the inside and outside walls is less than an appreciable fraction of the wave length of the highest frequency to be transmitted. The principal limits on the narrowness of the section are the allowable tolerances in manufacture, as it can be seen that a given error in dimensions will have a relatively greater effect on the performance when the section is very narrow. The proper compromise is left to the judgment of the designing engineer.

The width of the section at the center of the turn, that is, whose center line is normal to the main center line of the horn Fig. 5 may be called t, and has the value,

$$t = \frac{D^2}{4a}$$

After the first turn is calculated so that all requirements both acoustical and mechanical are met satisfactorily,

* "Graphs for Exponential Horn Design", A. J. Sanial, *RCA Review*, July 1938.

the second or reverse column is computed. Either wall may be laid out experimentally and the other calculated from either of the equations.

$$a = \sqrt{b^2 + D^2} \text{ or } b = \sqrt{a^2 - D^2}$$

If the section of the column is relatively narrow, it is just as well to lay out the tentative wall as a straight line; it is easier to compute the other side; it simplifies manufacture and the performance is not affected.

This second section may progress backwards parallel to the main center line, it may rise at an angle or it may be bent. It will be found best perhaps to work it out so that the inner diameter gradually increases. This tends to keep the section thin so that by the time the second turn is reached, an abnormally large radius of curvature does not have to be used to satisfy the path length requirements referred to above. Of course if the bell diameter is fixed, the diameter of the horn at the second turn must not be greater than the bell diameter and should be less.

After the second turn is calculated the same as the first, the outer bell can then be laid out as its diameter is fixed at both ends. All that remains to find is the shape of the inner "mushroom" to give the final exponential section. If the design is now such that the diameter of the second turn is appreciably smaller than the outer bell diameter, the theoretical center line of the horn will be divergent, Fig. 6. This indicates that the directional response will not be as sharp as it might be made. On the other hand, it is usually found that in meeting all the other requirements that are laid down at first, there is only a small difference in these two diameters. This results in a sharper directional characteristic due to the manner in which the center line of the final section falls, Fig. 7. It is readily seen that considerable flexibility is offered by this type of horn for controlling the emerging sound and radiating it over a wide angle or a narrow beam as desired. There is, of course, the variation in the radiation angle with frequency which is always present from a source other than a point source, but this variation will be very much smaller in a properly designed concentric folded horn than that inherent in the ordinary straight exponential horn.

As for the effect of errors and inaccuracies, some are serious and others negligible. It is important to keep the spacing between the walls such that the correct area is maintained, and if this is not done, the response becomes very ragged and objectionable peaks are introduced. However, if the center mushroom is properly

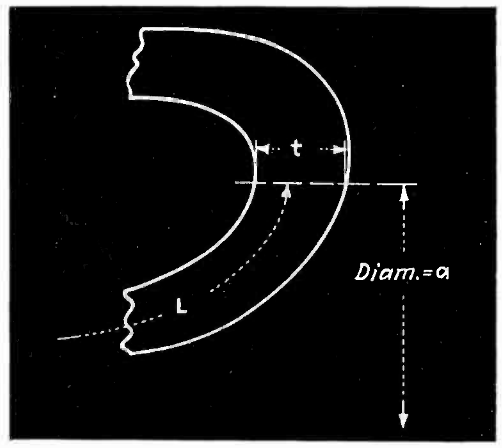


Fig. 5—Section at center of turn of horn

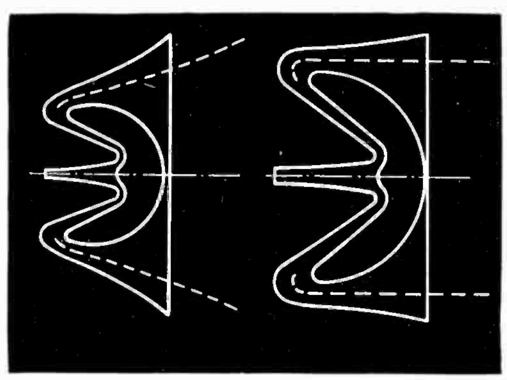


Fig. 6 and 7—Section at center lines of horn

spaced, but slips to one side, the effect will only be serious in changing the direction of the main beam of sound. As the actual cross sectional area is not affected, the horn itself will perform as expected. Errors in computation must be carefully checked as considerable undesirable effects can be introduced by either abrupt changes in section or by expansion less than the exponential rate. A decrease in sectional area is particularly bad. These errors introduce peaks and dips in the response and cause overall reduction in the efficiency.

It has been claimed by some that the efficiency of this type of horn is extremely high compared to the equivalent trumpet. This is not quite correct, the difficulty arising from the fact that acoustic efficiency is not generally understood and also that it is difficult to measure. Efficiencies have been set on the basis of pressure measurements on the axis with no attempt to integrate the total power over the whole sphere of which the horn is the center. When most of the sound is projected in a narrow cone in front of the speaker, the efficiency based only on pressure measurements in this cone is of course high. In fact, it would be possible on this basis to arrive at values of efficiency that are absurd. For this reason the fairest and simplest method of comparing loudspeakers is to 1) measure the pressure on the axis at a reasonable distance such as 10 feet, in open air, at a known electrical power input, and 2) measure the directional characteristic under like conditions. Speakers of a given classification as regards directional response can be compared readily, and if it becomes necessary to compare any with respect to total acoustic output, sufficient data are available to compute this.

Experimental Data

An experimental horn was built in accordance with the above methods with a mouth diameter of more than two feet. In recent tests the horn was set up on a dock at the relatively slight elevation of 12 feet, and pointed out over the water. The sound pressure measured on a launch with a standard make meter was 1/2 dyne per sq. cm. at a distance of one mile from the speaker with approximately 80 watts electrical input. As the speech signals were loud and distinct at this distance, the tests were repeated at farther distances. At two miles, even with noise from boats in the vicinity, the speech was still heard As the angle between the water surface and the speaker beam was only a matter of minutes at this distance, it can be seen that much of the sound was lost by reflection, so that greater distances than this could be covered under more favorable conditions.

The pressure of the beam dropped rapidly, so much so that it did not sound louder than an ordinary speaker would when standing to the side of it. One of the main advantages of this is the ability to use a microphone out in the open within a reasonable distance of the loudspeaker.

During these tests the microphone was less than 35 feet from the horn and directly back of it, and no sound proof booth or enclosure of any kind was required to prevent feed-back.

Television Deflection Circuits

By E. W. ENGSTROM and R. S. HOLMES

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THE deflecting circuit in a television receiver performs the function of supplying a force which acts on the electron beam in the Kinescope. This force is of such a type that it deflects the beam in the same manner and in synchronism with the electron beam in the Iconoscope at the transmitting station. For rectilinear scanning this force must have a linear change while the beam is traversing one line (or field) sweep, and a rapid return to the original condition at the end of the line (or field) sweep. Thus the time-amplitude curve of the deflecting force is of sawtooth wave shape with a slow, linear, rise and a rapid fall.

The forces producing the horizontal and vertical deflection must, of course, be arranged so that they produce beam deflections at right angles to each other. The vertical and horizontal deflection periods (or frequencies) are determined by the standards chosen for field and frame frequency and the number of lines per frame. For the standard 441 lines, 30 frames, 60 fields per second, interlaced, the vertical deflection period is 1/60 second and the horizontal deflection period is 1/13,230 second.

The force producing the deflection may be either a magnetic field or an electrostatic field. For television deflecting circuits the deflection may be magnetic for both horizontal and vertical, electrostatic for both or a combination of the two. (For example, magnetic vertical and electrostatic horizontal.)

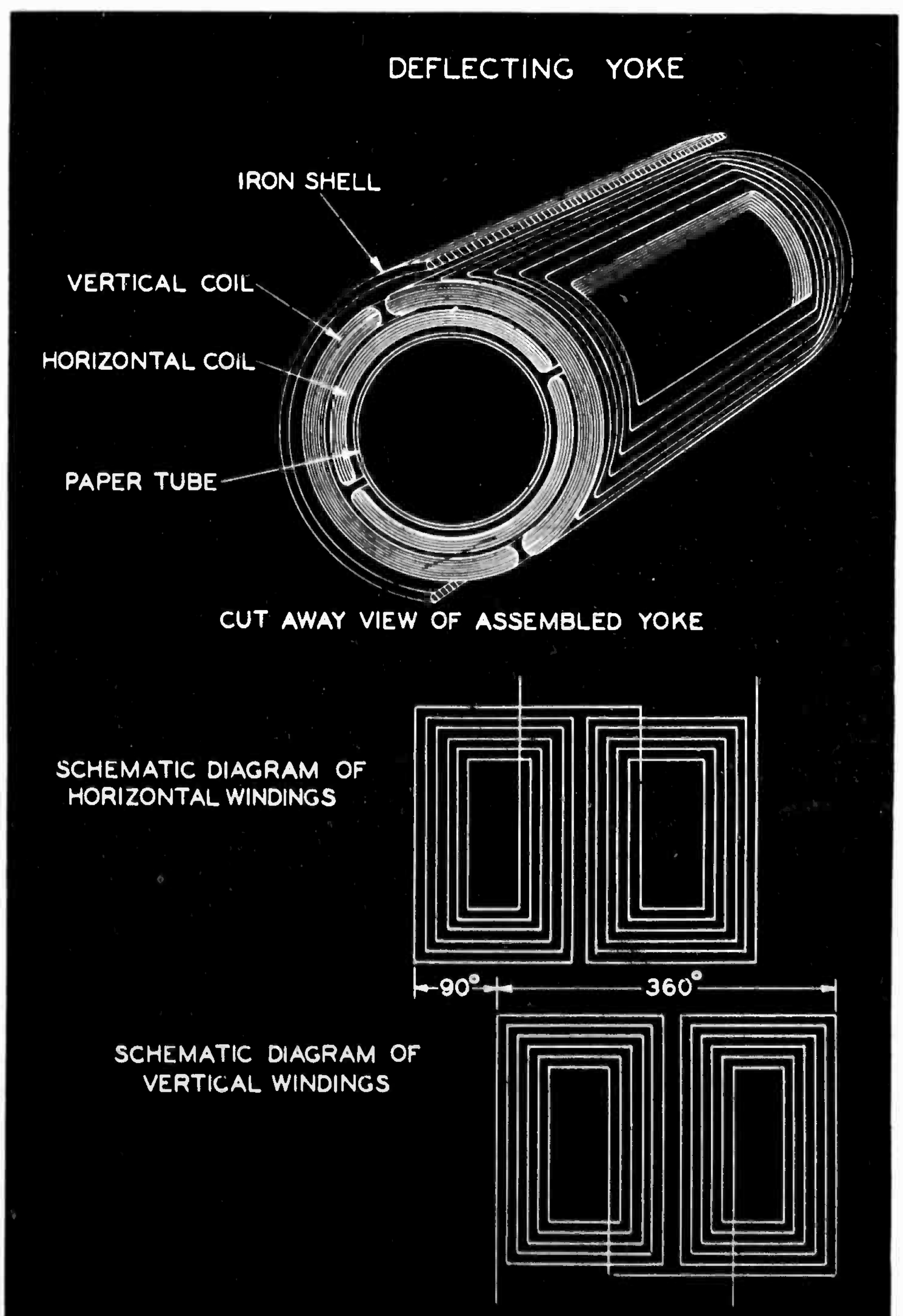
For electrostatic deflection a sawtooth wave of voltage is impressed on deflecting plates which are usually placed inside the cathode ray tube just beyond the beam generating gun. The beam is bent, or deflected, an amount proportional to the instantaneous voltage applied to the plates. This form of deflection is used in most oscillographs and has been dealt with quite extensively in the literature.

For magnetic deflection a sawtooth wave of current is passed through coils arranged around the neck of a cathode ray tube just ahead of the gun. This sawtooth of current produces a sawtooth wave of magnetic flux through the neck of the tube. This flux deflects the beam of electrons in proportion to its intensity.

It is very important that the distribution of flux across the tube neck be uniform, otherwise there will be deflection wave shape distortion or beam defocusing. Special care must be taken in designing the deflecting coils in order to insure this uniform flux distribution.

One form of coil arrangement which has been found to be satisfactory is shown in Fig. 1. Each coil is wound rectangular in form, and is made up of several concentric sections each having the proper number of turns so that the magnetic flux will be uniform in the finished yoke. The coils are then formed around a paper tube just large enough to slip over the neck of the Kinescope. The two horizontal coils are placed on the inside, 180° apart, and the vertical coils are formed over them and placed exactly 90° from the horizontal coils. Thus the horizontal coils provide a magnetic flux at right angles to that of the vertical coils, so that the resultant

Fig. 1—Magnetic deflection yoke with winding polarity indicated



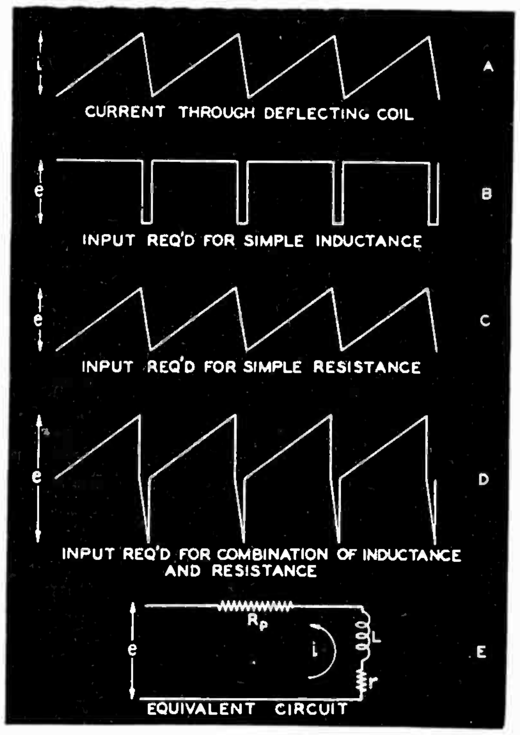


Fig. 3—Wave shapes in linear deflecting output circuit

horizontal deflection is at right angles to the vertical deflection.

There is an iron shell around the outside to increase the inductance of the vertical coils and provide shielding.

It is necessary that the cross coupling between the horizontal and vertical windings be small to prevent reactions between them. It is sometimes desirable to reduce this coupling by inserting an electrostatic shield between the two sets of windings. However, it has been found that this is not necessary if one or both of the sets of windings is made low impedance so that large voltages are not present across the windings. In the yoke described the horizontal coils are relatively low impedance and are driven from a high ratio step-down transformer, while the vertical windings are somewhat higher in impedance and are driven through a relatively low ratio step-down auto transformer.

Figure 2 is the schematic circuit diagram of an experimental receiver using this type deflecting yoke. Two power pentodes operating in parallel are used to drive the horizontal deflecting coils. The current supplied by these tubes must, of course, be of sawtooth wave shape, as shown at A in Fig. 3. The wave shape of the voltage required on the grid of the output tube (or tubes) to produce this sawtooth of current depends on the tube impedance and the coil inductance and resistance. In its most simplified form the equivalent circuit of this combination is shown at E of Fig. 3. This circuit is correct providing the output tube is operating over the linear portion of its characteristic.

If this circuit consisted simply of L, and if the coil resistance (r) and the tube plate resistance (R_p) were both zero the input required would be $E = L\frac{di}{dt}$, which would be a wave such as is shown at B. If, on the other hand, the circuit had consisted of simply resistance, the input required would be $E = IR$, which would be a wave such as is shown at C. For a circuit consisting of both resistance and inductance the required input would be a combination of the two, such as shown at D.

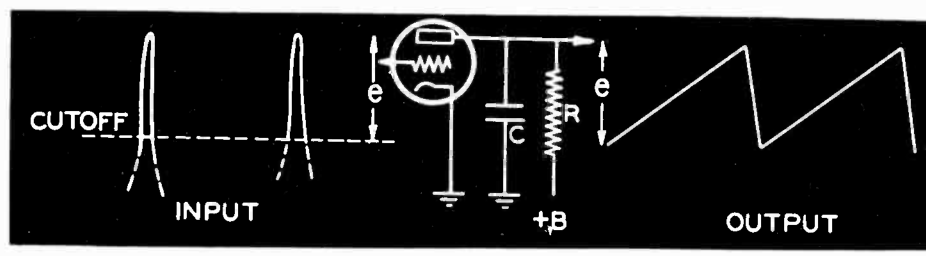


Fig. 4—Discharge tube circuit

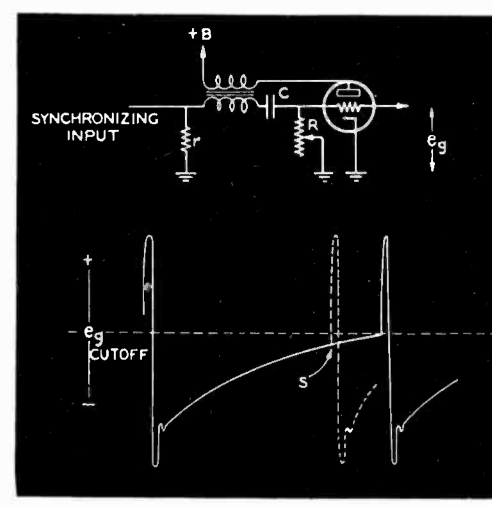


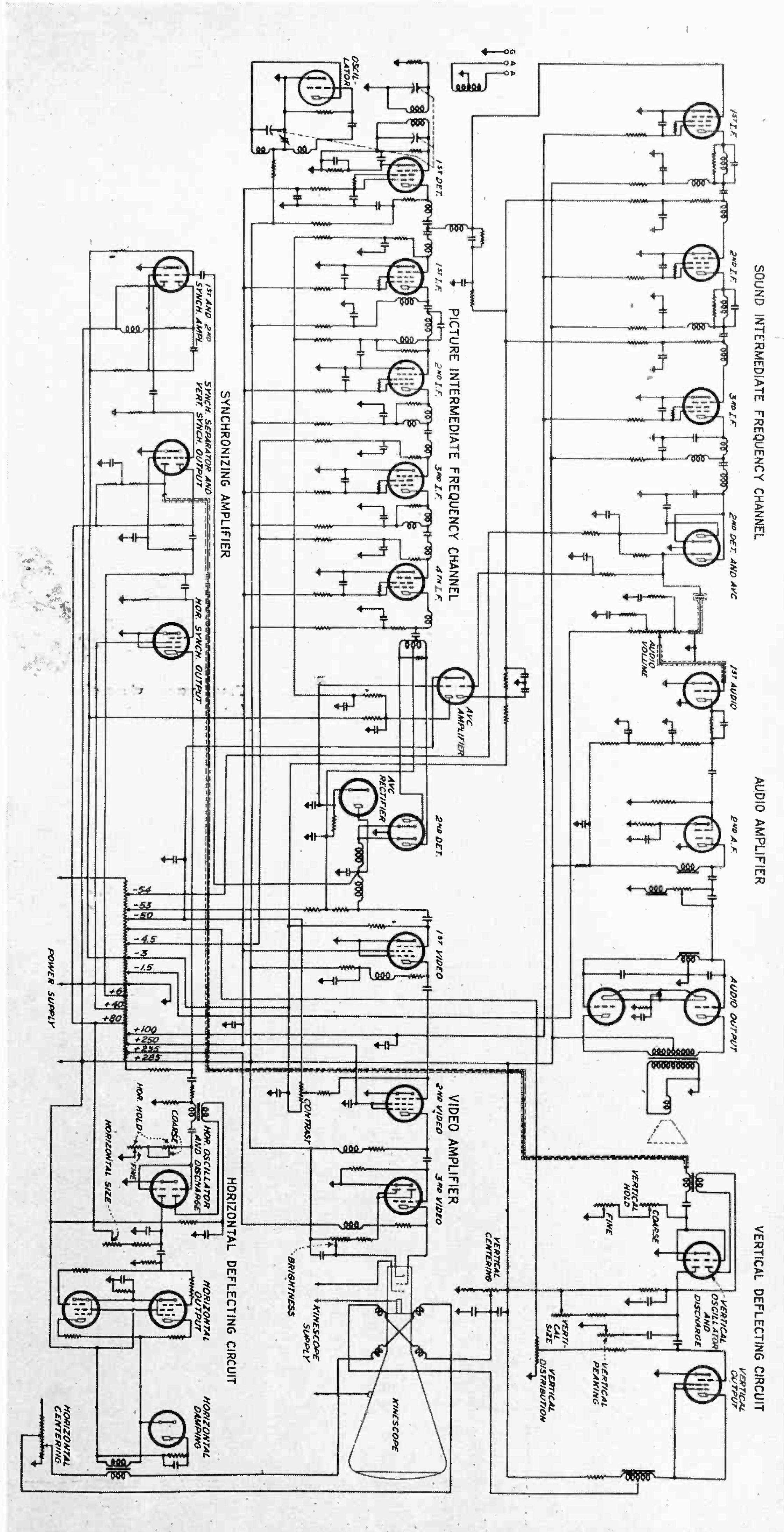
Fig. 5—Blocking oscillator

In the horizontal deflecting circuit, pentode output tubes are used. These tubes have a high plate impedance. It is so high, in fact, that the circuit inductance L becomes practically negligible and the voltage required on its grid is essentially a simple sawtooth, as shown at C in Fig. 3. Because of the high impedance of the output tubes, they offer very little damping to the inductance L, so that when the current suddenly changes a transient condition is set up which must be damped out. If simple RC damping were used across the inductance the loading would be present on both the build up and decay of the current. This would lengthen the return time, which is undesirable. A diode in series with the RC load circuit acts as a switch to remove the load during the return time while still preventing the transient during the active scanning time. This is the "horizontal damping" tube on Fig. 2.

The stepdown transformer between the horizontal output tubes and the deflecting coils must have a good frequency and phase characteristic to pass the sawtooth of current. The period of the sawtooth wave is 1/13,230 second, and for good transmission approximately 10 harmonics of this frequency must be passed, so the transformer must pass frequencies from about 13 to 130 kc. The leakage inductance and capacity of the transformer must be small so that the natural period of the complete output system is in the order of 130 kc.

The sawtooth voltage wave to be applied to the grids of the horizontal output tubes is generated in the discharge tube circuit. The operation of this tube is illustrated in Fig. 4. The grid is normally maintained at a bias beyond cutoff, but is supplied with a positive impulse at the end of each scanning line by the oscillator. In its plate circuit is a capacitor (C) connected from plate to ground and a large resistor (R) from plate to a high positive voltage ($+B$). During the period between grid impulses the capacitor charges at essentially a constant rate through the resistor R. When the impulse drives the grid to zero (or positive) voltage the capacitor is discharged through the tube, thus generating the sawtooth in synchronism with the grid impulses. The values of R and C are so adjusted that the peak charge on C never exceeds a small percent of the +B voltage, thus assuring a practically linear rise in voltage across the capacitor during the charge period.

Fig. 2—Circuit diagram of receiver employing magnetic type deflection



The oscillator is of the type known as a "blocking" oscillator. Its operation is illustrated in Fig. 5. The circuit is simply that of a grid leak biased oscillator, but the constants are such that during the first half cycle of oscillation the grid is driven into grid current, during which time the capacitor C is charged. The grid is then driven far beyond cut-off by the collapse of the plate current, and is maintained beyond cut-off by the charge on C. This charge gradually leaks off through R until cut-off is reached, when plate current starts, driving the grid positive until plate current saturation is reached, when it again collapses and the cycle is repeated. The period of the oscillation T is determined principally by the constants RC while the sharpness of the pulses generated are principally determined by the transformer constants.

Synchronization

Synchronization may be accomplished by impressing positive synchronizing pulses on the grid circuit, as, for example, across r. If these synchronizing pulses are of sufficient amplitude to drive the grid up to cut-off they will start plate current flowing and initiate a new cycle. This is illustrated at S on Fig. 5. The new cycle would then be as shown by the dotted curve. Thus, for this method of synchronizing the period T should be somewhat longer than the period between synchronizing pulses. The period T is normally adjusted until the oscillator "holds" by adjusting R, the "Hold" control. The amplitude of the synchronizing signal required is greater the more T differs from the synchronizing period. Thus, if extraneous pulses, such as noise signals, are present in the synchronizing signal they will have little effect on the oscillator hold unless they exceed the amplitude of the synchronizing pulses.

The positive portion of the blocking oscillator output wave actuates the discharge tube as described.

The oscillator and discharge circuits for the vertical deflection are similar in performance to those of the horizontal, but the circuit constants differ because of the difference in time for a cycle of operation.

(*Continued on page* 32)

A Frequency Monitoring Unit for Relay Broadcasting Stations

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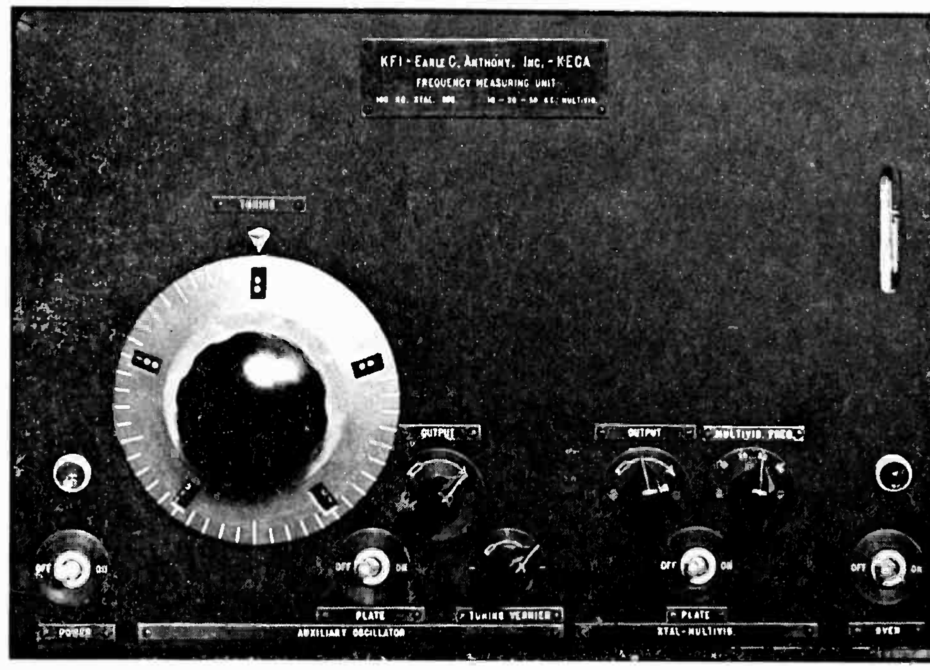


Front panel view of frequency monitoring unit. The thermometer for determining temperature of the crystal is shown at the right

MANY broadcasting stations make use of portable-mobile transmitters of comparatively low power for the purpose of forwarding special-event programs from remote locations where a telephone-line connection cannot be obtained. At the nearest available telephone facility a receiver is set up and the received program is sent from there on a program loop to the main equipment room of the station. These transmitters are usually licensed to operate on any one of four specific frequencies assigned somewhere between 1600 and 3000 kc. The equipment described herewith was designed to fulfill, at a moderate cost, the requirement for a frequency monitor for this class of station.

The regulations stipulate that a relay broadcast station of over 10 watts of power shall maintain its frequency to within 0.04 of 1%, and the frequency monitor used shall be accurate to within half of this figure or 0.02 of 1%. The described unit has an accuracy well within this limit. It is not required that the monitor be situated alongside the transmitter; this one is intended for operation at the receiving location.

The monitor is comprised of four units: a 100 kc crystal oscillator, a multivibrator, an auxiliary electron-coupled oscillator, and a voltage-regulated power supply. They are mounted on a 17″ by 12″ by 3″ chassis and a 10½″ by 19″ panel, the whole being arranged for a standard rack.

With coupling established between the receiver and monitor, signals will be heard from the 100 kc crystal oscillator at every 100 kc interval over the receiver dial up to about 7000 or 8000 kc. The multivibrator, controlled by the 100 kc standard, furnishes additional calibration signals which have a separation of 50, 20, or 10 kc as selected by appropriate switching, and which can be heard up to approximately 3500 or 4000 kc. The independently controlled auxiliary oscillator operates at frequencies between 500 and 1100 kc; its harmonics can be heard above 30 Mc.

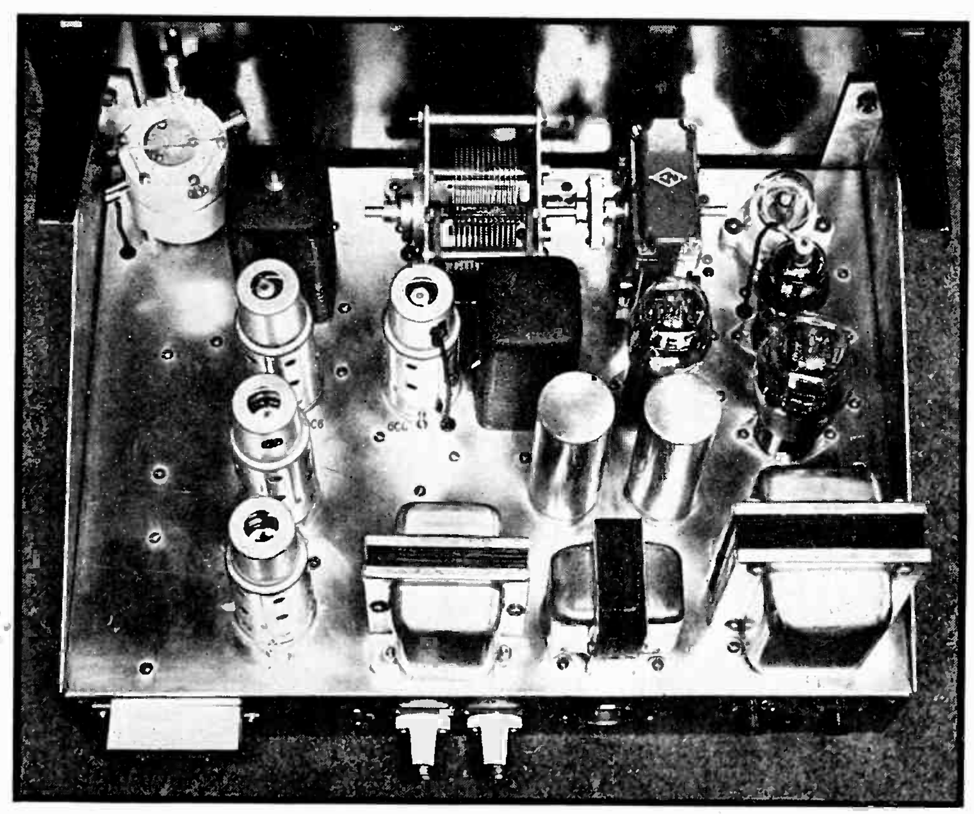
To begin a monitoring operation, the signal to be monitored is tuned in with the receiver. The auxiliary oscillator is turned on and a certain one of its harmonics is made to zero beat with the transmitter signal. The receiver is then tuned to the auxiliary oscillator, and the crystal oscillator-multivibrator is turned on. An audio beat note will then be obtained at the output of the receiver as a result of the beating of the auxiliary oscillator signal with that from the crystal-multivibrator unit. This audio beat note is then fed on the program loop to the main equipment room where the audio oscillator is assumed to be located. The operator on duty there compares the audio signal on the program loop with the tone from the audio oscillator and adjusts the frequency of the latter until the two tones are in zero beat. The frequency of the program-loop signal can then be determined by consulting the frequency calibration of the audio oscillator.

Depending upon the frequency of the transmitter being monitored, the audio beat note resulting from the above series of operations will have a certain specified frequency corresponding to correct on-frequency operation of the transmitter. This specified frequency is determined beforehand by the use of simple arithmetic. The amount of transmitter deviation will be shown by the amount that this audio note is above or below its correct value, as explained in detailed examples to follow.

First it might not be amiss to examine briefly the components of the monitor. The crystal oscillator employs a Bliley 100 kc crystal which has a temperature coefficient of 3 cycles per megacycle per degree Centigrade. It is contained in a compact Isolantite oven; the whole unit is mounted by plugging into a 5 prong socket. A thermometer, viewed through the front panel, shows the temperature in the oven which is maintained at an even value by a thermostatically controlled heater. A small 10 volt filament transformer furnishes current for the heater and the indicating pilot light. The oscillator circuit is one recommended for low-frequency standards. The inductance in the oscillator tank circuit is furnished with the crystal. By means of the two-section variable condenser which tunes this tank circuit, the crystal oscillator frequency may be varied over a range of about 100 cycles. This permits calibration of the crystal against some primary standard, as for instance the standard frequency signals of WWV.

The multivibrator circuit is a two-stage, resistance-coupled amplifier with the output connected back into the input. Such an arrangement will go into sustained oscillation and the frequency of oscillation can be governed by adjustment of the resistive or capacitative elements of the amplifier circuit. By means of R_{23} a portion of the 100 kc output of the crystal oscillator is injected in series with the d-c plate voltage of the multivibrator tubes. Under these conditions, and when the natural oscillating frequency of the multivibrator is adjusted to coincide with a subharmonic of the injection frequency, the oscillations of the multivibrator will fall into step and be controlled by the injected standard. Thus, if any of the circuit elements are adjusted so that the multivibrator frequency is approximately that of the tenth subharmonic, or 10 kc, the controlled output will include all the harmonics of the 100 kc standard plus all the harmonics of 10 kc contributed by the multivibrator. A similar result can be obtained using any order of subharmonic although control may be difficult above the tenth. The second, fifth, and tenth are used in this unit corresponding to multivibrator frequencies of 50, 20, and 10 kc respectively. The adjustable circuit element is the grid leak of the first tube which may be either R_{11}, R_{10}, or R_9, according to the position of the multivibrator-frequency switch S_3. The potentiometers making up R_9, R_{10}, and R_{11}, are accessible from the bottom of the chassis and were made variable only for ease of preliminary adjustment. With the switch S_3 on the 100 kc position the grid leak is shorted out and the multivibrator is inoperative.

Values for R_9, R_{10}, and R_{11} are determined by trial as follows. With the crystal oscillator operating and S_3 on the 50 kc position, vary R_{11} slowly from minimum resistance. Listen to the signal in a receiver and adjust until only one response is heard between any two 100 kc signals. This should occur with the potentiometer set at approximately the resistance given in the schematic diagram. The 100 kc markers can be identified beforehand with the switch at the 100 kc position. Similarly, with S_3 at the 20 kc position, adjust R_{10} until four signals are heard between any two 100 kc markers. Then R_9 should be adjusted until nine responses can be counted in the 100 kc interval. A beat-frequency oscillator, if available in the receiver, will aid in locating these responses. The portion of the receiver dial to be used should be selected so that there are no interfering signals to be heard from outside sources.



Rear view of the monitoring unit. Except for the quartz crystal in the upper right corner, the construction is similar to that of a radio receiver

The combined output voltage of the crystal oscillator-multivibrator unit appears in the plate circuit of the 6C6G and is made available at a standoff insulator on the rear of the chassis. It is controlled from the front of the panel by means of potentiometer R_1. Other controls associated with the unit which appear on the front of the panel are the plate voltage switch, the multivibrator-frequency switch, the oven-heater switch, and the heater pilot light.

The auxiliary oscillator employs a 6C6G in the usual electron-coupled circuit. Almost any combination of coil and condenser can be used; they should be proportioned so that the oscillator frequency will cover as much as possible of the broadcast band. A small vernier condenser, connected in parallel with the main tuning condenser, assists in making close adjustment to zero beat. The r-f output voltage of this oscillator appears on a second standoff insulator on the back of the chassis, and is varied by means of potentiometer R_{16}. The frequency drift, after a half-hour warming up period, has been found to be approximately 120 cycles per hour.

The regulated power supply contributes considerably to the frequency stability of the auxiliary oscillator under conditions of varying line voltage or varying load (as when the multivibrator is turned on and off). The base-voltage for the regulating system is the constant voltage drop across the 1 watt neon tube. The limiting resistor has been removed from the base of this tube. The power supply output voltage is adjustable from the bottom of the chassis by means of the potentiometer R_{21}. Good regulation will not be obtained unless the output voltage is maintained above a certain minimum. In the case of this unit the minimum is about 200 volts. When the voltage is 210 volts there is practically no variation in output voltage from no-load to full-load operation, or with changes in line voltage between 100 and 120 volts. A condenser (C_{15}) across the neon tube is for the purpose of squelching high-frequency oscillations in the neon tube circuit if any are experienced. The condenser size is to be determined by trial.

To examine in detail a typical monitoring operation, assume that the transmitter frequency is 1606 kc and assume further that coupling has been established between receiver and monitoring unit as explained a little later on. The operating procedure would then conform to the following outline:

1. Tune receiver to transmitter (1606.000 kc).
2. Turn on auxiliary oscillator and tune it (to 535.333 kc) until its third harmonic zero beats with transmitter.
3. Tune receiver to the second harmonic of auxiliary oscillator (1070.666 kc).
4. Turn on crystal-multivibrator, with MV switch at the 10 kc position, thus obtaining 666 cycle beat between the second of the auxiliary oscillator (1070.666 kc) and the multivibrator (1070.000 kc).
5. Send this tone to equipment room and have it measured with audio oscillator. If the transmitter is on frequency, the tone should measure 666 cycles. If it is different than 666 cycles, the transmitter deviation will equal 3/2 of the difference. Thus, if it measures 766, the transmitter is 150 cycles high; if it measures 600, the transmitter is 99 cycles low, etc.
6. Check: Frequency of beat obtained in operation 4 should increase when auxiliary oscillator frequency is increased a small amount. If it does not, the deviation will equal 1000 cycles plus 3/2 of the beat frequency, and will be negative.

Preparations incidental to the above would include the following:

a) Turn on everything and allow preliminary warm-up. The crystal oven will reach its final temperature in about ten minutes.

b) Connect from receiver antenna post to the output terminal of the crystal-multivibrator unit.

c) If transmitter can be heard satisfactorily without antenna, do not connect antenna to receiver. If it is necessary to use antenna, disconnect it after operation 2 above.

d) Turn off the two plate-supply switches just before starting the measurement.

The output of the auxiliary oscillator is high enough so that a direct connection from its output terminal to the receiver is usually not required. If an increased coupling is needed in order to use the higher order harmonics, it can be obtained by connecting to the oscillator output a short length of wire which is twisted around the lead going to the receiver antenna post.

As a further example, suppose the transmitter frequency to be at the higher end of the band, say at 2758 kc. The procedure would then be:

1. Tune receiver to transmitter (2758.000 kc).
2. Turn on auxiliary oscillator and tune it (to 919.333 kc.) until its third harmonic zero beats with transmitter.
3. Tune receiver to the fundamental of the auxiliary oscillator (919.333 kc).
4. Turn on crystal-multivibrator, with MV switch at the 20 kc (or 10 kc) position, thus obtaining a 666 cycle beat between the fundamental of the auxiliary (919.333 kc) and the multivibrator (920.000 kc).
5. Send this tone to the equipment room and have it measured with audio oscillator. If the transmitter is on frequency, the tone should measure 666 cycles. If it is different than 666 cycles, the transmitter deviation will be equal to three times the difference. Thus if it measures 766 cycles, the transmitter is 300 cycles *low*; if it measures 600 cycles, the transmitter is 200 cycles *high*, etc.
6. Check: Frequency of beat obtained in operation 4 should decrease when the auxiliary oscillator frequency is increased a small amount. If it does not, the deviation will equal 2000 cycles plus 3 times the beat frequency, and will be positive.

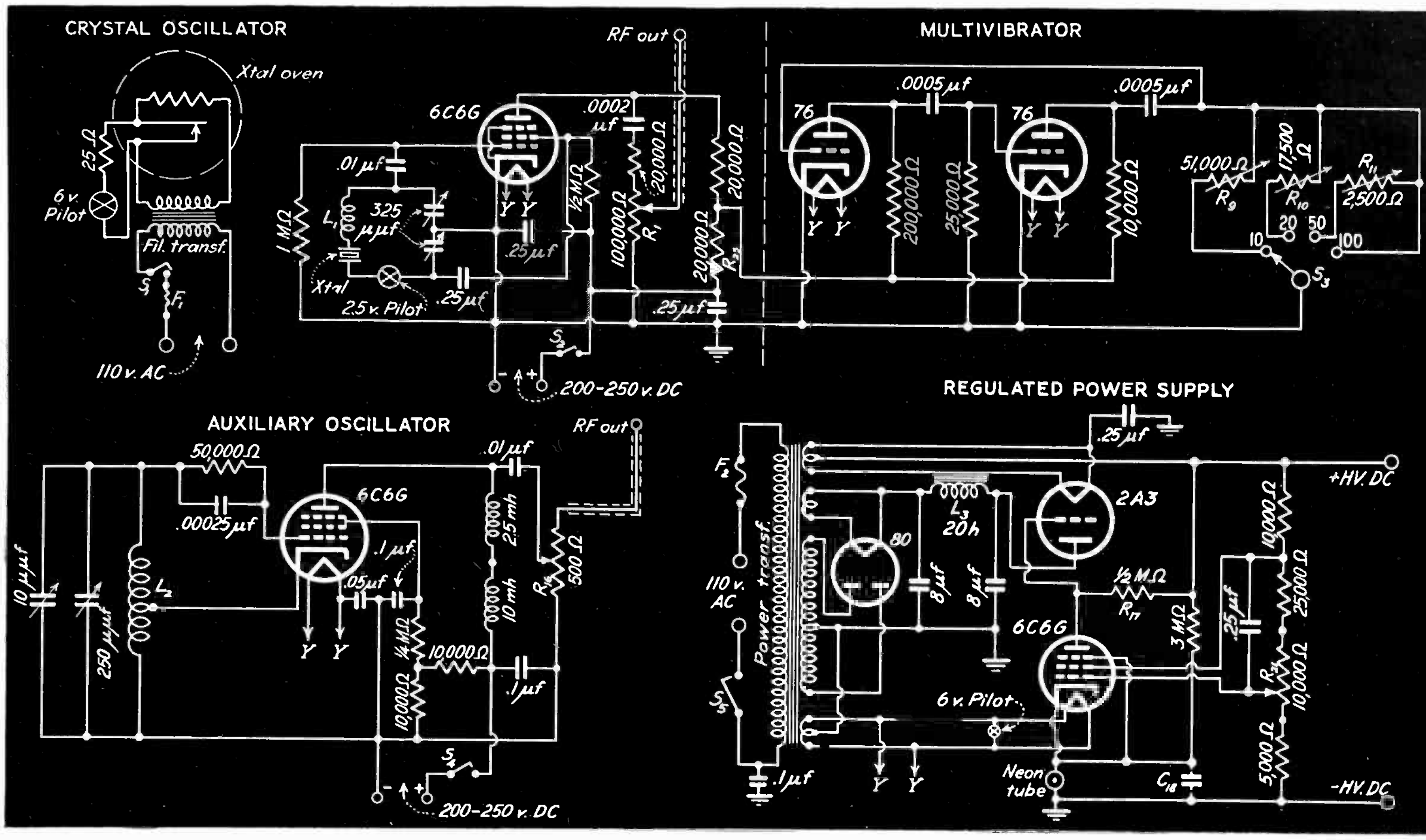
It is to be observed from the above two examples that a beat note (obtained in operation 4) which varies from its specified value in a certain direction does not necessarily indicate a transmitter deviation in the same direction. In the first example, transmitter deviation in the plus direction is indicated by a beat-note frequency greater than 666 cycles, while in the second example the opposite is true. The direction of change depends upon the relationship existing between the frequencies of the multivibrator and auxiliary oscillator that are used in operation 4.

If the transmitter deviation is assumed to increase in a certain direction, the frequency of the beat note resulting in operation 4 will decrease to zero and then increase again as the transmitter deviation becomes still greater in that same direction. Thus in the first example if the transmitter deviation is 1000 cycles in a negative direction the auxiliary oscillator would be tuned to 535.000 kc (operation 2), its second harmonic would be 1070.000 kc (operation 3), and the beat frequency of operation 4 would be zero since the multivibrator is also 1070.000 kc. If the transmitter deviation is assumed to increase still further in the negative direction, say to 1300 cycles, the resultant beat will be increased to a value of 200 cycles. Finally, with a transmitter deviation negative and equal to 2000 cycles, a beat of 666 cycles will be obtained and the transmitter deviation would be erroneously quoted as equal to zero on the basis of information given under operation 5.

Transmitter deviations as great as those mentioned in the preceding paragraph are not likely to occur especially if low temperature coefficient crystals are used in the transmitter. However, the possibility of overlooking such a deviation must be eliminated, and that is the purpose of operation 6. The problem resolves itself to that of determining whether, in operation 4, the frequency of the auxiliary harmonic is above or below that of the multivibrator. This can be quickly learned by intentionally increasing the auxiliary oscillator frequency by a small amount, at the same time listening to the beat in the receiver and noting whether it increases or decreases in frequency. If the change is not as stated in operation 6, then the second method must be used in determining the transmitter deviation.

A still further possibility exists in that the transmitter deviation might be so great as to cause the frequency of the second harmonic of the auxiliary oscillator (example 1) to approach within a few hundred cycles of either 1060 or 1080 kc. Since multivibrator signals exist at these two frequencies also, an audio beat would result and an incorrect value of deviation would be assumed. This large amount of deviation is still more unlikely to occur and it would be at once apparent from the frequency calibration of the receiver dial or of the auxiliary oscillator dial. A further check could be carried out by changing the multivibrator switch from the 10 to the 20 kc position and noting if the auxiliary signal which causes the beat in operation 4 is an odd or even multiple of 10 kc.

The difficulties discussed in the preceding three paragraphs would also be experienced if the auxiliary oscillator were to drift in frequency between the times of operations 2 and 4 by an amount comparable to the value of resultant beat. That is, in the first example if the funda-



Schematic wiring diagram of the complete monitor consisting of crystal oscillator and oven, multivibrator frequency multiplier, auxiliary oscillator and regulated power supply

mental of the auxiliary were to drift downwards 333 cycles between operations 2 and 4 an erroneous zero beat would be obtained at the completion of operation 4. Similarly, in example 2, a drift of 666 cycles upwards would also produce an erroneous zero beat. Such a possibility is conclusively eliminated if, at the end of operation 4, the receiver is retuned to the transmitter and a recheck made to determine that the auxiliary oscillator harmonic is still zero beating with the transmitter.

Various harmonics of the auxiliary oscillator may be used in operations 2 and 3, or it may be possible to beat the transmitter signal directly against the signal from the multivibrator. In planning the procedure to be used for any given transmitter frequency, the frequency of the audio beat note finally obtained at the end of operation 4 is of course the most important factor. It should be high enough so that usual amounts of deviation will not cause the resultant beat to approach zero frequency. It should be low enough to permit good accuracy in reading the frequency calibration of the audio oscillator, especially if the higher order harmonics are used in operation 2.

It will be noted that during a measurement it is necessary to tune the receiver to two different r-f signals. In the first case it is to be tuned to the transmitter, and in the second case to the auxiliary oscillator. The accuracy with which this tuning is done has no effect upon the accuracy of measurement since the receiver is used in both cases merely as an indicator to show when two independent r-f signals are in zero beat with each other. When the auxiliary oscillator signal is being made to zero beat with the transmitter, careful adjustment of the auxiliary oscillator frequency will produce a flutter in the receiver response which will gradually decrease in rapidity as exact zero beat is approached. Adjustment to obtain this further and to bring it down to a very slow rate of change is a refinement in zero beating which is desirable but not necessary. Tuning to simple zero beat anywhere below 15 to 20 cycles will provide an accuracy well within the lowest tolerance.

Probable errors of measurement—

1. Error due to incorrect crystal frequency:

   The greatest variation in oven temperature would not exceed 2 degrees Centigrade, corresponding to a frequency error of 6 cycles per megacycle. The highest extension of this error would be to 3000 kc, involving a net error of 18 cycles.

   This assumes that the crystal oscillator has been previously calibrated against a dependable standard to assure that the tank tuning condenser is correctly set.

2. Error due to frequency drift of the auxiliary oscillator:

   The accuracy of a measurement depends upon freedom from drift from the time of operation 2 until the completion of operation 5. This should not require more than 2 or 3 minutes but assume that ten minutes is used. This corresponds to a drift of the fundamental of approximately 20 cycles.

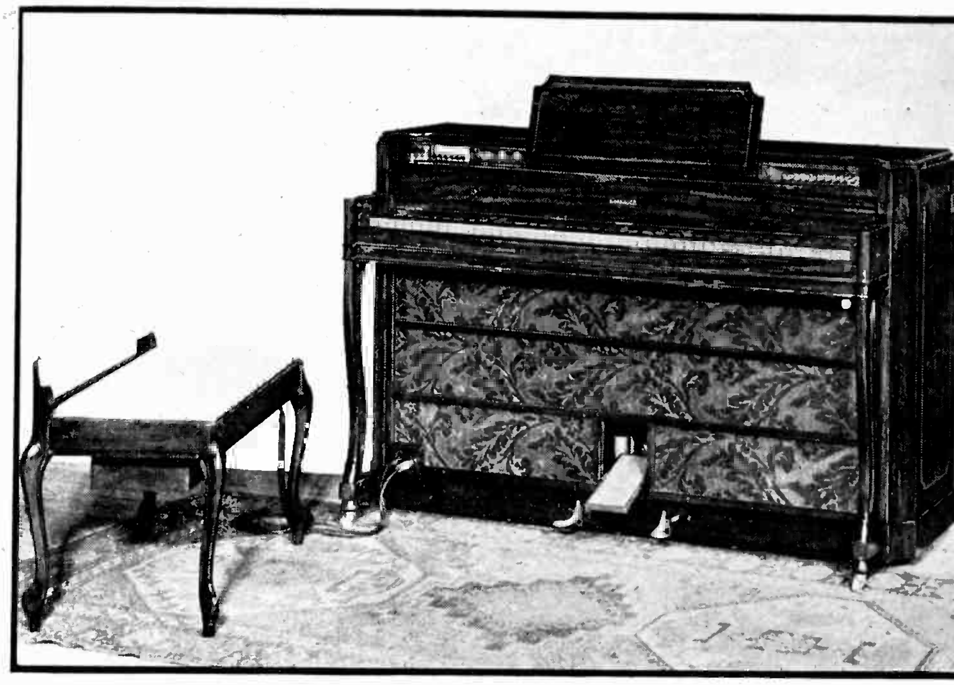
   The net error in this case will depend upon the order of harmonic used in operation 2, and will be less if another harmonic is used in operation 3. At the lower transmitter frequencies where the tolerance is less, expressed in cycles, it will not be necessary to use harmonics higher than the third in operation 2.

   Accordingly, if the fundamental drifts 20 cycles, the audio beat will be wrong by 20 cycles, and the error in quoting the deviation will be 3 times 20 or 60 cycles. Regulation of the power supply prevents appreciable change in auxiliary oscillator frequency when the MV is turned on at the beginning of operation 4.

3. Error due to improper beating of r-f signals:

   The operator is required to make one r-f adjustment for zero beat in operation 2. If the flutter effect is used, the adjustment can be made correct to within one cycle or less. By tuning to simple zero beat the harmonic of the auxiliary will be correct to within approxi-

(Continued on page 33)



THE ELECTONE

—an electronic piano

—By GORDON S. TAYLOR

THE piano is perhaps the closest approach to a "new" musical instrument that has been achieved in recent centuries. It was based on older instruments, going all the way back to the harp of biblical time. The innovation wrought in the piano is found in the fact that its strings are struck by a hammer while in its predecessors the strings were plucked either by hand or by mechanical arrangements.

Even this musical infant, the piano (pianoforte) dates back to about 1700 and the original instrument created at that time bears a striking likeness to the Grand piano of today. The instrument has, of course, been greatly improved since then but these improvements have been in the nature of refinements rather than basic.

During the past forty years many efforts have been made to develop fundamentally new instruments; all without any marked degree of success. With the development of vacuum tubes this activity increased tremendously.

One instrument is of particular interest because it combines the old and the new in a manner which provides the important factors of utility, versatility, compactness and economy, and by no means the least, the ordinary playing technique of the piano. It is the "Electone", developed by Maurice K. Bretzfelder of Krakauer Brothers piano company and licensed under the Miessner Patents.

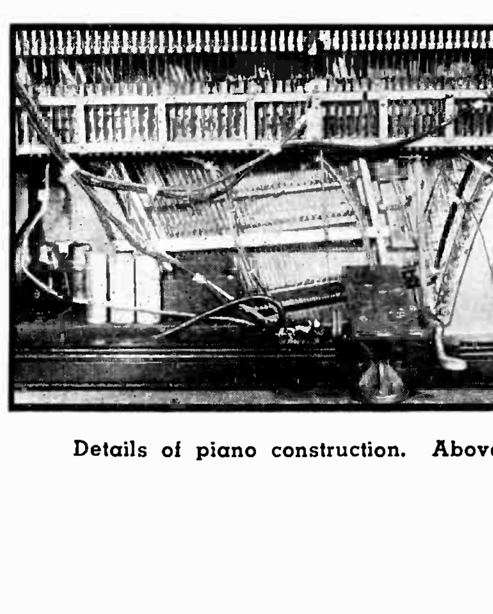
The Electone is fundamentally a piano in that it employs standard piano action, strings and keyboard. Its distinction lies in its ability to effectively simulate numerous instruments including the organ and others of the wind, reed and string varieties.

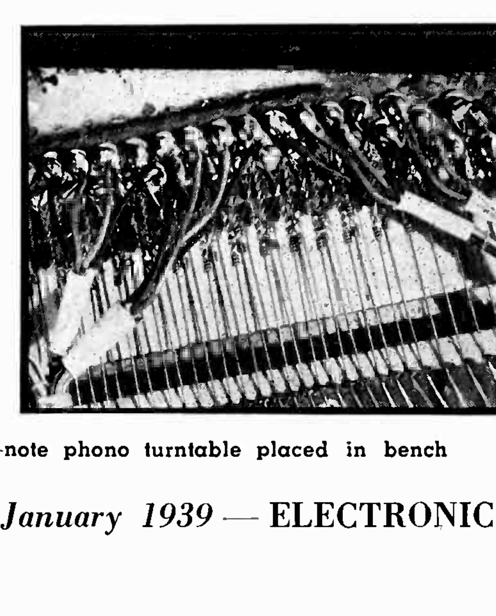
In appearance the instrument is identical with the modern Console piano; the normal sound board is eliminated however and pick-ups, amplifiers, mixers, loudspeaker and other electrical devices are added to provide electrical reproduction and the alteration of tone characteristics necessary in the reproduction of instruments other than the piano.

In describing its operation it is more simple to first consider its operation as a piano. The strings are actuated in an entirely normal manner but due to the absence of the sounding board the direct audible response is negligible. Instead, the vibrations are translated into electrical energy, amplified and reproduced through the medium of the loudspeaker.

Certain advantages of this method of reproduction are at once apparent. The volume range is limited, for instance, only by the gain and power handling ability of the amplifier system; and within this range by a conventional volume control. Tone is likewise regulated as desired by means of treble and bass controls similar to those employed in more ordinary amplifier applications, providing for the first time some ability to adapt the tone of a piano to the acoustics of the room in which it is located. Thus with this small piano the volume range of a Grand piano is readily attained or exceeded, and a degree of acoustic adaptability is provided.

As in an ordinary piano the relative volume varies with the touch of the player on the keys and in every other respect the instrument is played as any other piano except that the tone and volume controls permit a much wider range of expression.





Details of piano construction. Above—note phono turntable placed in bench

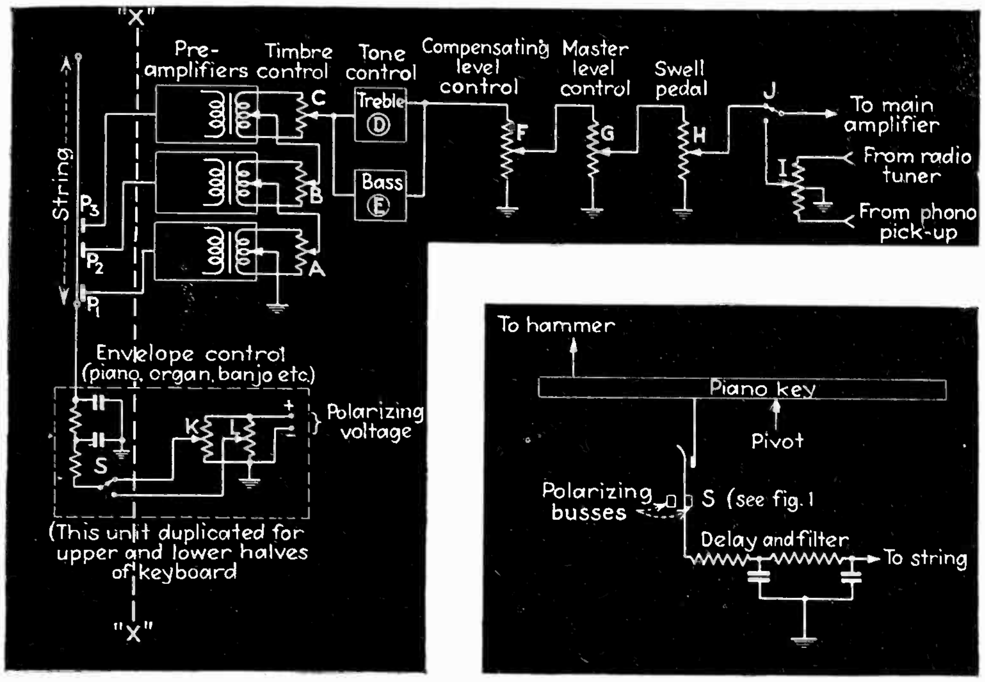


Fig. 1—Controls A to F inside piano; fully variable for preliminary adjustment. Ten "Timbre Selector" buttons on control panel above keyboard provide 10 preselected combinations of A, B and C with D, E and F automatically co-ordinated for each. Controls G, I and J are on keyboard control panel; H is foot pedal. Controls K and L are inside piano but are duplicated by a 3-position toggle switch on control panel which provides choice of piano, organ or plucked string envelopes. Two such switches control each half of keyboard independently. Equipment to left of dash line "X" is duplicated for each of the 88 strings, a switch (S) being mechanically connected to each key. Figure at right—detail of polarizing voltage application.

Still further variety is afforded by the inclusion of other design refinements such as a "swell" pedal, an auxiliary volume control device by means of which the volume of sound may be made to increase rather than diminish after the keys have been struck.

Not the least of these refinements is inclusion of a headphone jack. With crystal headphones plugged in, the loudspeaker is automatically cut out and the player can hear himself without burdening neighbors—even in the next room.

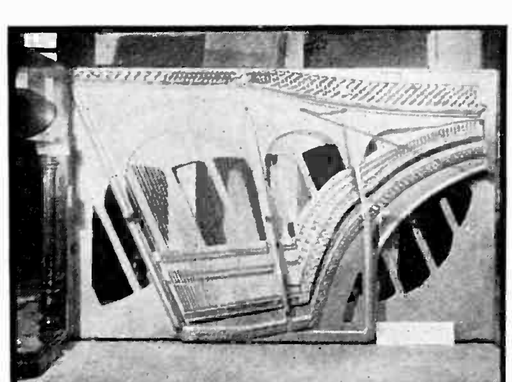
For straight piano reproduction (plus the refinements suggested) a single electrostatic pick-up at the bridge end of each string would serve the purpose of translation, picking up the fundamental and harmonics in normal proportion. In simulating other instruments, however, it is necessary to alter the harmonic composition and in the Electone this is accomplished by the use of three tiny plates distributed along each string, making a total of 264, the instrument having 88 notes.

The first group of pick-ups is located very close to the ends of the strings and therefore close to a node point so far as fundamental vibration is concerned. While these pick-ups are likewise close to the common node point of harmonic vibrations, they are at the same time less remote from the harmonic antinodes, especially those of the higher harmonics, and the overall result is a relative abundance of harmonics.

The second set of plates is placed approximately one-sixth of the length up the strings and the third set at approximately one-quarter length. At these two points fundamental pick-up is about equal and relatively high as compared with the first set of plates. The amplitude of other harmonics differs considerably at the three different positions. Certain harmonics that are strong at number three position may for instance be totally lacking at number two and weak at number one position. With other harmonics the reverse may be true.

The output of the 88 pick-ups comprising each set is fed to a preamplifier and the outputs of these three amplifiers are in turn connected into a phasing network as shown above.

By means of this network the three outputs may be made to buck each other or aid each other in any desired degree determined by the setting of the three knobs (A, B and C) controlling this action. Thus the fundamental may be accentuated or suppressed in almost any degree desired, certain harmonics may be accentuated while other harmonics and the fundamental are decreased, etc.



Placement of strings in piano

Placement of the three sets of pick-up plates is determined by trial rather than with a foot rule, to provide the greatest degree of phasing flexibility and therefore the widest variety of tone composition. To the uninitiated this may seem a lapse from good engineering practice but it is found to represent a short-cut readily justified by the results.

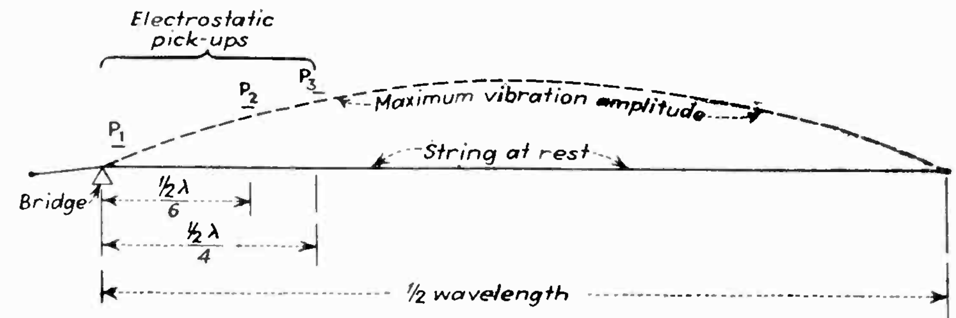
In this multiple pick-up system, a polarizing voltage is applied to the strings corresponding to the diaphragm of the condenser microphone while the three small plates correspond to the backplate. These plates are actually the heads of machine screws threaded through the frame behind the strings and slotted at both ends to permit adjustment from the rear by means of a screw driver. Their spacing from the strings is such as to provide the same degree of pick-up; that is, those located at the ends of the strings where the amplitude of vibration is small are turned in close to the static string, while those further up are spaced further away to allow for the greater amplitude of vibration which occurs at these points.

In imitating instruments of various types it is obvious that tone composition variations are essential, but likewise obvious that the sound envelope pattern is equally important. No matter how perfectly the tone characteristics of an organ were attained, the instrument would certainly not sound like an organ if each note started with a thump as it does in the piano, nor could a banjo be imitated without a strong initial surge such as occurs when a string is plucked.

To provide for these differences a polarizing voltage of predetermined value is applied to all strings continuously through individual SPDT switches mechanically attached to each key. When a note is struck this switch connects another polarizing voltage to the string, through a time delay network so that a fraction of a second elapses before the altered voltage becomes effective. The values of these voltages are adjustable. If the normal voltage is quite low and a high voltage is applied to the other side of the switch, the output of the electrostatic pick-ups will be low for a fraction of a second after a note has been struck, then will increase after a lapse of time corresponding to the delay period of the network. Reversing the voltages; i. e., making the normal voltage higher than the other, will reverse this action.

In piano reproduction, the two voltages are made equal by similar adjustments of controls *K* and *L*, and there is no delay action. In organ reproduction on the other hand, the normal voltage is made low and the second voltage high. The result is that while the strong vibration of the hammer blow is taking place the pick-ups are relatively insensitive but by the time this initial surge has diminished to normal sustained level the delay circuit has allowed the higher polarizing voltage to be applied to the string and the correspondingly higher sensitivity of the pick-ups maintains the same sound level as before, providing the polarizing voltages and the delay circuit constants have been properly selected. The envelope pattern in this case is thus made rectangular.

By making the normal voltage higher the piano thump is accentuated to correspond to the still higher initial surge of a plucked string. The ratio of sustained amplitude to initial amplitude varies with different types of plucked instruments but the two polarizing voltages are readily adjusted to meet any requirements.



Placement of pickup plates along string for various tonal effects

Inside of the piano, knobs are provided for varying these voltages, for phasing or mixing, for treble and bass attenuation, etc. But the player cannot be expected to have either the ability or the patience required to balance these various controls against each other to obtain realistic performance in imitating any particular instrument which he might desire at the moment. Certainly if he is playing a piano selection and wishes to interpolate a passage from another instrument he cannot stop to make these adjustments.

The designers have therefore provided means on the front of the instrument, just above the keyboard for instantaneous alteration of both the tone character (timbre) and the envelope. At the right is a group of ten push-buttons which constitute the timbre selectors. These buttons operate a 10-position, 6-gang switch by means of which not only is the desired tone characteristic obtained but the volume and tone controls are automatically adjusted to correspond.

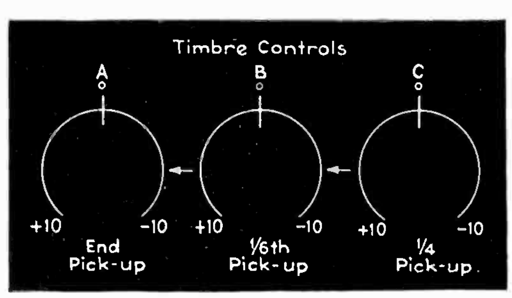
Above the keyboard to the left are two 3-way toggle switches. These are the envelope selectors providing the choice between piano, organ and "plucked" reproduction and correspond to three preadjusted positions of controls *K* and *L*. Each switch controls half the keyboard, making it possible to duplicate one instrument with half the keyboard and play the piano accompaniment with the other half.

Beside these switches is the master gain control (G) by means of which the overall volume may be regulated at will. The foot controls are identical with those of the normal piano except that the "swell" pedal (H) referred to before has been added.

While this instrument as described provides a tremendous variety and flexibility, its designers felt that it would provide still greater utility in the home, meeting all demands for home music and entertainment, if radio and phonograph were included. A push-button radio tuner is therefore built into the piano itself and a phonograph turntable and pick-up are incorporated in the bench. Both utilize the amplifier system of the piano.

Provision is also made for the use of additional loudspeakers, to be mounted externally where the instrument is to be used in the open or in indoor areas too large to be comfortably covered by a single speaker. It is pointed out that in restaurants it is usually desirable to distribute sound at relatively low level from several speakers rather than at high level from one point.

Controls correspond with controls A, B and C of Fig. 1. "o" = bridge balance point; not necessarily midpoint



TONE (Timbre)	* MIXING POSITIONS			Composition
	A	B	C	
Natural Piano	+10	0	0	Normal piano
	−10	0	0	
Thin, Reedy	±10	+10	−10	Harmonics accentuated Fundamental down
	±10	−10	+10	
Round	+10	+10	+10	Fundamental and harmonics up; fundamental stressed
	−10	−10	−10	
Woody, Thud-like	0	+10	+10	Fundamental up, Harmonics down
	0	−10	−10	

* Only extreme positions shown. Intermediate settings provide unlimited additional variations

Transmission Line Calculator

BY P. H. SMITH

Radio Development Department
Bell Telephone Laboratories

TRANSMISSION line problems are greatly simplified if the line is terminated by an impedance equal to its characteristic impedance. Standing waves of current and voltage are then eliminated, and if losses are neglected, the input impedance, current, and voltage at all points along the line are constant. Computations for the current and voltage under these conditions are based simply on Ohm's law. In communication systems this special condition is usually considered most conducive to efficient trouble-free operation.

There has long been a need for a simple means, without recourse to lengthy computations, for evaluating the impedance, current, and voltage at any chosen point along radio-frequency transmission lines in terms of specific values of the several transmission line parameters. This has led to the development of a special radio-frequency transmission-line calculator for solving many ordinary transmission-line problems.

There are four factors that generally enter the solution of problems involving the changing input impedance along a line. These are the characteristic impedance of the line, the load impedance, the length of the line, and the input impedance. If any three of these are known, the fourth may be found from the relationship:

$$Z_s = Z_0 \left[\frac{Z_r + jZ_0 \tan 2\pi L}{Z_0 + jZ_r \tan 2\pi L}\right]$$

Where L is the length of the line in wavelengths, Z_0 is its characteristic impedance, which for low-loss radio-frequency lines is essentially a pure resistance, Z_r is the load impedance, and Z_s is the input impedance.

The independent variable Z_0 will be a constant for any particular line, and consequently may conveniently be combined with Z_s and Z_r in the form of a ratio. With this transformation, the equation becomes:

$$Z_s/Z_0 = \frac{Z_r/Z_0 + j \tan 2\pi L}{1 + j(Z_r/Z_0) \tan 2\pi L}$$

For any one value of Z_r/Z_0 substituted in this equation a series of values for Z_s/Z_0 can be plotted for various values of L from zero up to one-half wavelength. Because L appears in the equation as an arc tangent, the curve will repeat itself for every half wavelength. If such a curve is plotted on a rectangular coordinate system with the resistance components along the abscissa axis and the reactance components along the ordinate axis, it will be found to be a circle with its center on the resistance axis. For other values of Z_r/Z_0 other curves could be drawn, and all would likewise be found to be circles with their centers on the resistance axis, but they would not be concentric. Such a set of curves is shown in Fig. 1.

Each of these curves, however, represents more than a single value of Z_r/Z_0. At the load end of the line, for example, where $L = 0$, Z_s will be equal to Z_r, which determines one point on the curve. Obviously every other point on the curve corresponds to another value of Z_r, when L is taken as zero at that point. This other value of Z_r, when substituted in the above equation, will give the same curve but with a different position for the point of $L = 0$. These curves, therefore, cannot be completely designated by a single value of Z_r/Z_0. It will be noted, however, that each curve gives a minimum and maximum value of Z_s/Z_0 which are the two points where the curve crosses the resistance axis. The ratio of the minimum to the maximum value of Z_s/Z_0, which is the same as the ratio of minimum to maximum Z_s, is different for each curve, so that each may be designated by the ratio of minimum to maximum input impedance that is peculiar to it. Each circle thus represents the input impedance over a half wavelength section for a family of transmission lines of various values of characteristic and load impedances, but alike in having the same ratio of minimum to maximum impedance. The ratios of minimum to maximum current or voltage will also be the same for any transmission line represented by a single curve, and may be designated by ρ, and these values of ρ are marked on the curves.

The points of minimum and maximum impedance on each curve are one-quarter wavelength apart, and all other points on the curves may be indicated as fractional wavelengths from the points of minimum or maximum impedance, as marked on the curves. If the points on the various curves at the same distance from the points of maximum impedance are connected by a line, the plot will appear as in

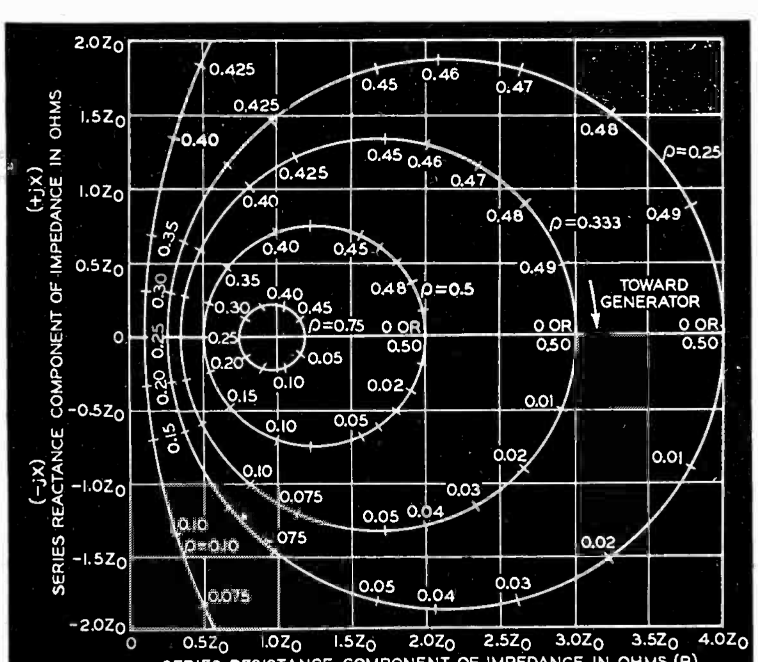


Fig. 1—Rectangular co-ordinate system forming the basis of the transmission line calculator. Resistance components plotted along abscissa; reactive components along the ordinates

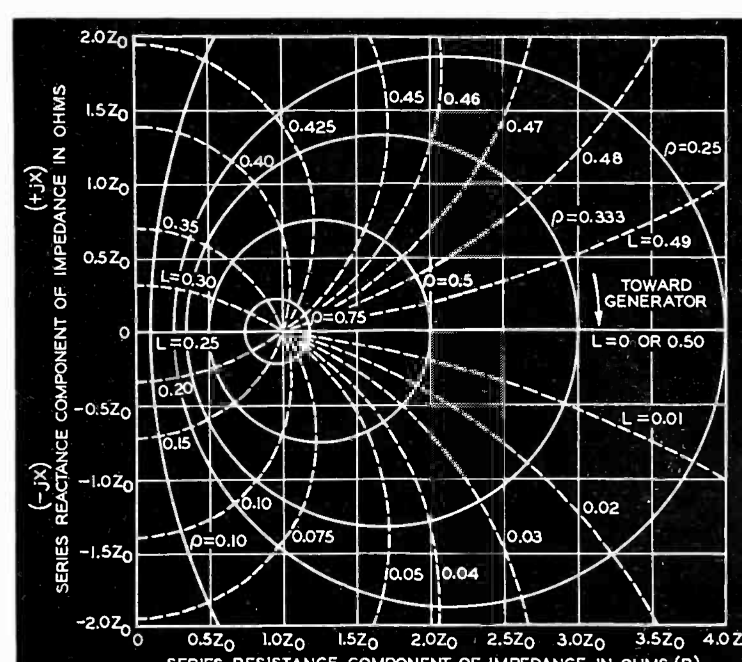


Fig. 2—Rectangular co-ordinate system similar to Fig. 1, but with dotted curves representing the locus of points at specified distances from the point of maximum impedance of the line

Fig. 2. These distance curves are also circles; their centers are on the reactance axis and they intersect the original family of circles at right angles. Each of the these curves is marked with a value for L which represents the distance in wavelengths to the point of maximum impedance.

Such a set of curves could be used to solve various transmission line problems. Assume, for example, that the resistance component of the load impedance was $2.7Z_0$ and the reactance component of the load impedance was $-0.9Z_0$. This value of impedance is found to lie on the circle marked $\rho = 0.333$. The intersection at this point of the circle marked $L = 0.02$ simply indicates the distance to an arbitrary reference point where the impedance is maximum. This point on the curve actually represents the conditions at the load end of the line—where $L = 0$. The impedance at any other point, for example .08 wavelengths toward the generator, may be found by following clockwise around the circle marked $\rho = 0.333$ the required distance to the intersecting circle where $L = (0.02 + 0.08)$, or 0.10. At this point the impedance will be found to be $0.8Z_0 - j\ 1.0Z_0$.

This information may be arranged in a much more convenient form, however, by a transformation of coordinates that converts the rectangular mesh of resistance and reactance coordinates into coordinates comprising two families of circles intersecting each other at right angles. If the curves of constant ρ, and constant L were plotted on these transformed coordinates, the ρ curves would be found to be concentric circles and the L curves would be equally spaced straight lines radiating from the center of the ρ circles. Instead of actually plotting the curves, however, an arm may be pivoted at the center of the ρ circles, and by providing a slide on this arm, any of the ρ circles may be described merely by rotating the arm with the slide fixed in the proper position. By the addition of an adjustable distance or L scale around the periphery, the impedance at any point along the line may be readily determined.

A calculator of this type has been constructed to facilitate the solution of transmission-line problems, and is shown in Fig. 3. The resistance and reactance coordinates are marked as a ratio to Z_0; thus a marking of 1.6 on a resistance circle means a resistance of 1.6 times Z_0. The arm is graduated with a scale for ρ, and so the slide can be set to any desired value. The distance scale, which rotates around the periphery of the diagram, is marked from 0 to 0.5 wavelength by two scales reading in opposite direction, so that distance can be read in either direction from any initial starting point on the coordinate system.

In using this calculator the length of the line and its characteristic impedance, Z_0, will, for example, be known. If in addition both the resistance and reactance components of the impedance at any point of the line are known, the values of the impedance at all other points, including the input impedance, and the location of the points of minimum and maximum impedance, current, or voltage, are readily found.

Assume for example that the load impedance is known. The corresponding impedance point would be located on the coordinates of the calculator, and the arm and slide would be moved until the center line of the arm and the cross line of the slide intersected over this point. The ratio of minimum to maximum voltage, or current could then be read directly from the scales on the arm. The zero point of the outer distance scale would then be set under the center line of the arm, and the distance to the resistance axis of the calculator, corresponding to zero reactance, would then be the distance to the nearest point of minimum or maximum impedance. Here the impedance is a pure resistance, and the distance to this point is read on the distance scale in wavelengths. The value of this minimum or maximum resistance is determined by moving the arm to this position and reading the value under the line on the slide. The impedance at any other point, which might be the input end of the line, is found by moving the arm the required distance and reading under the intersection of slide and arm. If the distance were more than a half wavelength, one or more half wavelengths would, before moving the arm of the calculator, have to be subtracted from the total distance so that the remaining equivalent distance will be less than a half wavelength.

At the load end of the line the impedance is Z_r, and this same value of impedance will be found every half wavelength down the line as indicated in Fig. 4, where the successive points where $Z = Z_r$ are marked. Between any two such points there will be a point of minimum impedance, and one of maximum impedance. At these points the impedance is a pure resistance. These points, which are represented on the calculator by the transverse axis of zero reactance, are always a quarter wavelength apart. The distance between them and any other point may be read from the distance scale.

For most radio frequency transmission lines where the insulating medium between conductors is chiefly air and the attenuation is negligible, the velocity of transmission is practically the same as that of light. The distance scale around the edge of the calculator is laid out in terms of wavelengths as measured on the transmission line. For transmission lines having considerable attenuation and especially those having an appreciable amount of high dielectric insulating material interposed between conductors, there may be a marked reduction in the velocity of transmission, and a correction factor must be applied to the distance scale. This correction is proportional to the reduction in the velocity of transmission which can be measured or computed from line constants.

To extend the utility of the calculator to audio-frequency telephone lines or to other transmission lines, which may have an over-all attenuation up to 15 decibels, an attenuation scale expressed in 1 decibel intervals is provided along the adjustable arm. The zero point along this scale will be variable and consequently, the scale intervals are not numbered. For any particular problem, however, the zero point will be found where the sliding cross-hair on the arm intersects the scale when the slider is first adjusted to any known transmission line impedance. If the problem subsequently requires a movement of the rotatable arm along the distance scale "toward generator," the attenuation scale will extend from this zero point in the direction of the center of the calculator, or vice versa, as is indicated on the scale. It is necessary only to count off the required number of decibels along the scale. Moreover, if the input impedance at any two points along a transmission line is known, the attenuation of the line can be obtained directly from this scale. This will be indicated by the number of decibel intervals along this scale which the slider moves across when going from one impedance setting to the other. It should be notd, however, that for lines with reduced velocity and appreciable attenuation, the characteristic impedance Z_0 may be complex, and the complex value should then be used to obtain the impedance quotients expressed as coordinates on the calculator.

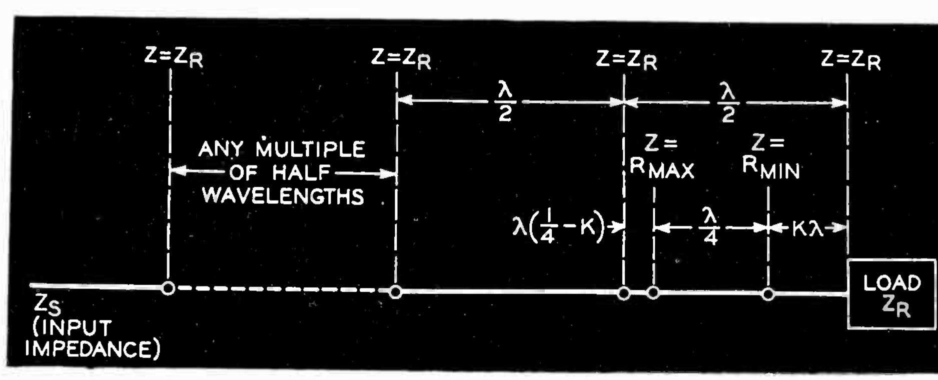


Fig. 4—Distance-impedance diagram for loaded transmission line

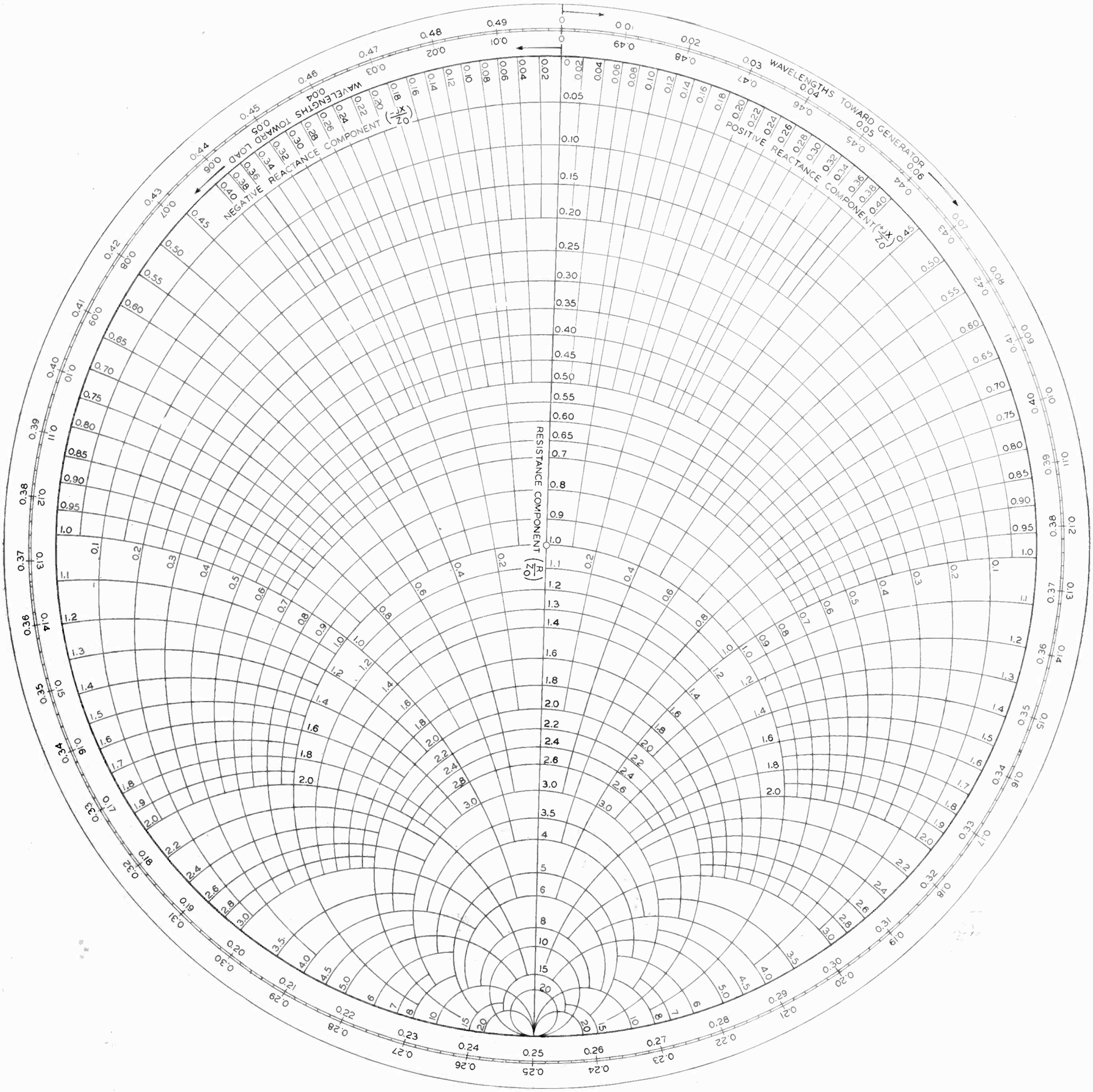
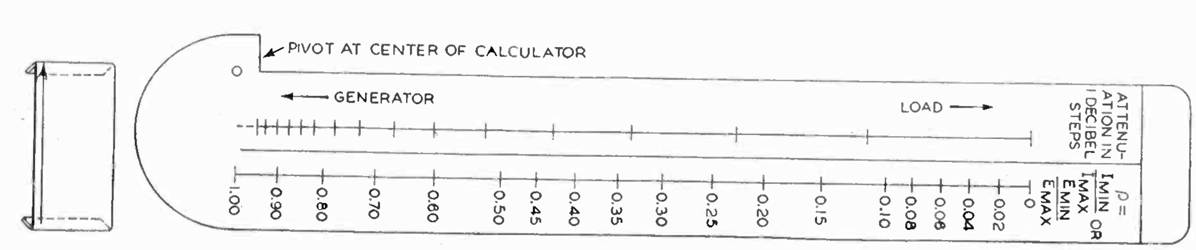


Fig. 3—Circular form of transmission line calculator. The arm, shown below, is to be pivoted at the center of the circular chart. For convenience, a transparent slide may be slipped on the rotating arm



Television Deflecting Circuits

(*Continued from page* 21)

The vertical output tube is a triode in the experimental receiver of Fig. 2. The plate impedance of the tube is, therefore, lower. Also the inductance in the plate circuit is higher due to the much lower operating frequency. The voltage wave required on the grid of the vertical output tube is, therefore, that required to drive a sawtooth of current through a resistance and inductance in series, such as that shown at D in Fig. 3. To generate this type of a wave in the discharge tube circuit a resistor may be placed in series with the charging capacitor, indicated by the "Vertical Peaking" control on Fig. 2. Adjusting the value of this resistor changes the amplitude of the impulse relative to the sawtooth component.

Because of the lower operating frequency of the vertical no damping is required across the coil to prevent transients, so no damping tube is required. They return line requirements are much more easily met in the vertical than in the horizontal.

In this series of articles all the components of a television receiver except the power supplies have been discussed. In the next article the power supplies will be discussed, and some aspects of the complete receiver will be described.

Initial Drift in Photocells

(*Continued from page* 15)

varying four times as rapidly as the filament current, the intensity could be adjusted to 0.01 per cent. Allowing for experimental inaccuracies, any drift in illumination could scarcely have exceeded 0.1 per cent.

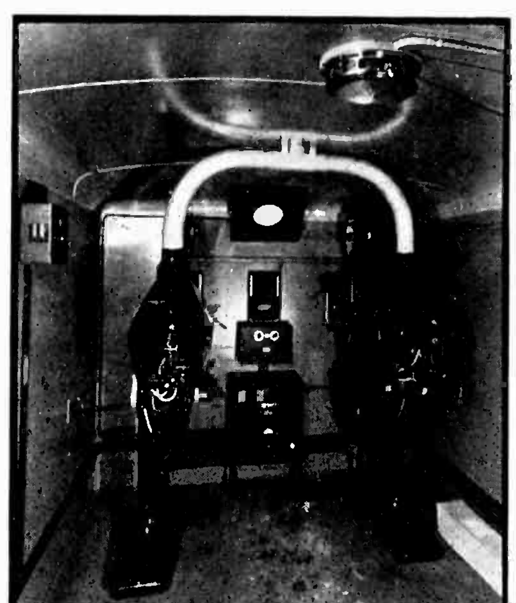
To minimize temperature drift, a column of distilled water in a cylindrical glass vessel at room temperature was interposed in the path of light so that its great heat capacity would tend to stabilize the thermal system. Also, it was capable of absorbing a large part of the long-wavelength end of the spectrum.

Currents delivered by the cell were read by a conventional microammeter, values being estimated to approximately 0.1 per cent. The apparatus could be manipulated in such manner that a first significant reading could be obtained 20 seconds after the cell was exposed. The second reading was taken at the end of the first minute and so on at intervals of one minute. No cell was exposed for a series until it had had a 24 hour recovery period in the dark. Readings for the five cells for a given load resistance were repeated on a later day, so that ten sets of data were available for obtaining the separate curves plotted in Fig. 2.

It will be observed that there is a slight negative drift for short-circuit conditions and a slight positive drift for open-circuit conditions. For intermediate values of load resistance, the drift appears to be at least as small as the experimental uncertainties of measurement. Circuit resistances which are generally recommended for these cells to minimize the effective temperature coefficient and to obtain maximum power output are from 1000 to 2000 ohms. Therefore, in normal circuits the initial drift in Photox cells is negligible.

In Fig. 2 are added two curves of initial drift for a widely used selenium cell which is known to have a good degree of permanence. The data for these curves were measured under the same conditions as for the copper-oxide cells, but show a different order of magnitude of drift.

MOVIES ON WHEELS



Spacious portable projection truck for Roumanian theater is used to give outdoor motion picture performances. A 50-watt amplifier is used to feed the loud speaker system. The engine is used to drive a generator for supplying the required electrical power

Monitoring Unit for Relay Broadcasting Stations

(*Continued from page* 25)

mately 20 cycles, and the net error will be 20 cycles.

4. Error of measurement with the audio oscillator:

(a) Commercially built oscillators such as those which are calibrated with a vibrating reed, have a rated accuracy of 2%.
The net error from this source will also depend upon the order of harmonic used in operation 2, and will be less if another harmonic is used in operation 3. Further it will be proportional to the frequency of the audio beat. At the lower transmitter frequencies, the error need not exceed that represented by use of the third harmonic of the auxiliary in operation 2 with a resultant audio beat of 1000 cycles.
Accordingly, if the 1000 cycle beat is measured to within 2%, or 20 cycles, the deviation will be quoted with an error of 3 times 20 or 60 cycles.

(b) The zero beat adjustment between the audio tones can be made without difficulty to within less than 1 cycle.

(c) The accuracy with which the frequency calibration of the audio oscillator can be read and its effect upon the whole measurement is determined by the same factors mentioned in part (a) above.
At 1000 cycles, the oscillator dial should be readable to the closest 25 cycles; the net error from this source is then 3 times 25 or 75 cycles.

Total expected error—

Error due to incorrect crystal frequency	18 cycles
Frequency drift of auxiliary oscillator	60 cycles
Improper zero beat at r.f.	20 cycles
Error in audio oscillator	60 cycles
Error in reading audio oscillator dial	75 cycles
Total	233 cycles

The tolerance quoted in the regulations will have a minimum value of 320 cycles corresponding to transmitter operation at the lowest assigned frequency of approximately 1600 kc. The estimated error arrived at above, although adverse conditions have been assumed, is still almost 100 cycles below the maximum allowed. The use of reasonable discretion and care in planning and carrying out an operating procedure will substantially reduce the actual error to values less than the estimated. Moreover it will be expected that some of the errors will cancel each other since it is unlikely that they will all occur in the same direction.

Multilayer Coil Inductance Chart

Design of multilayer inductance coils simplified through the use of families of curves relating various parameters of coil design. Form of chart lends itself readily to the solution of many types of design problems

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THE design of multilayer coils for a specified inductance presents difficulties because of the complexity of the equations derived to apply to such cases, and because of the large number of factors which must be considered since they affect the inductance. These factors include the inner and outer diameters of the coil, the thickness of the coil winding, the shape of the cross sectional area of the windings, and the space factor of the windings. A number of equations have been developed for the determination of inductance for multilayer windings, but a considerable saving of time may be effected through the use of the accompanying chart, which, upon measurement on a large number of coils, has been found to be accurate to within 5% except in a few exceptional cases.*

In the design of this chart, the variable factors selected are:

- $A = BC$ = cross sectional area of the coil winding in square inches
- B = width of coil winding, or cam width, in inches
- C = depth of coil winding in inches
- d = the outer diameter of the wire plus its insulation, and
- N = the number of turns of the coil.

When these factors are known, the chart may be used to determine the value of L/N^2, and since N is known, the inductance in microhenries may then be determined.

The cross sectional area of the coil, A, is determined by the diameter of the wire, d, and the number of turns, N, from the relation, $A = K d^2 N$ where K is the space factor of the winding. The numerical value for K is usually about 1.25, but this will vary with the adjustments of the winding machine, such as the tension of the wire during winding, and the number of turns per layer. Fortunately, variations in K, and hence in A cause much less than a proportionate variation in the inductance. Consequently it will seldom be necessary to use a value of K other than 1.25 which has been found to be quite satisfactory.

In the above equation, the value for d for ordinary wire is merely the overall diameter of the wire plus its insulation. For litzendraht wire, d may be taken as the overall diameter of a close symmetrical grouping, plus insulation. The relation between the number of strands, S, and the overall diameter of the litzendraht without silk or cotton insulation, d_o, is shown in the following table:

S	d_o
3	$2.16\, d_s$
5	$2.7\, d_s$
7	$3.0\, d_s$

where d_s is the diameter of each strand with its enamel insulation.

The inductance chart is designed in the form of several families of curves. Each family of curves corresponds to a different coil width, B, so that the width of the coil winding determines which family of curves is to be used in any design problem. The particular curves in any given family which are required for design purposes depends upon the area of the coil winding, A, the inner diameter of the coil form, D, as well as upon the shape factors D/C or C/B. The values of A are plotted as abscissa and the values of L/N^2 as ordinates on the main set of co-ordinates. Values for the coil width are indicated by the letter B at the right of each family, whereas the value of the inner coil diameter, D, for the almost horizontal lines is given at the left of each family of curves. The shape factor C/B is given as auxiliary abscissa, while the shape factor D/C is indicated by the almost straight lines at an angle of approximately 45° with the main co-ordinate system.

Values of the parameters and contours have been indicated by arrowheads on the corresponding curves or lines to eliminate any possible confusion as to their reference. The ordinate scales for the upper and lower families of curves will be found at the left side of the chart. The abscissa scale for all the left hand families of curves is along the lower edge, and that for the right hand families of curves is along the right edge of the chart. The abscissa scale for the center family of curves ($B = \frac{3}{8}$) is directly below these curves. Interpolation may be used, of course, within or immediately outside of the range of the chart plotted.

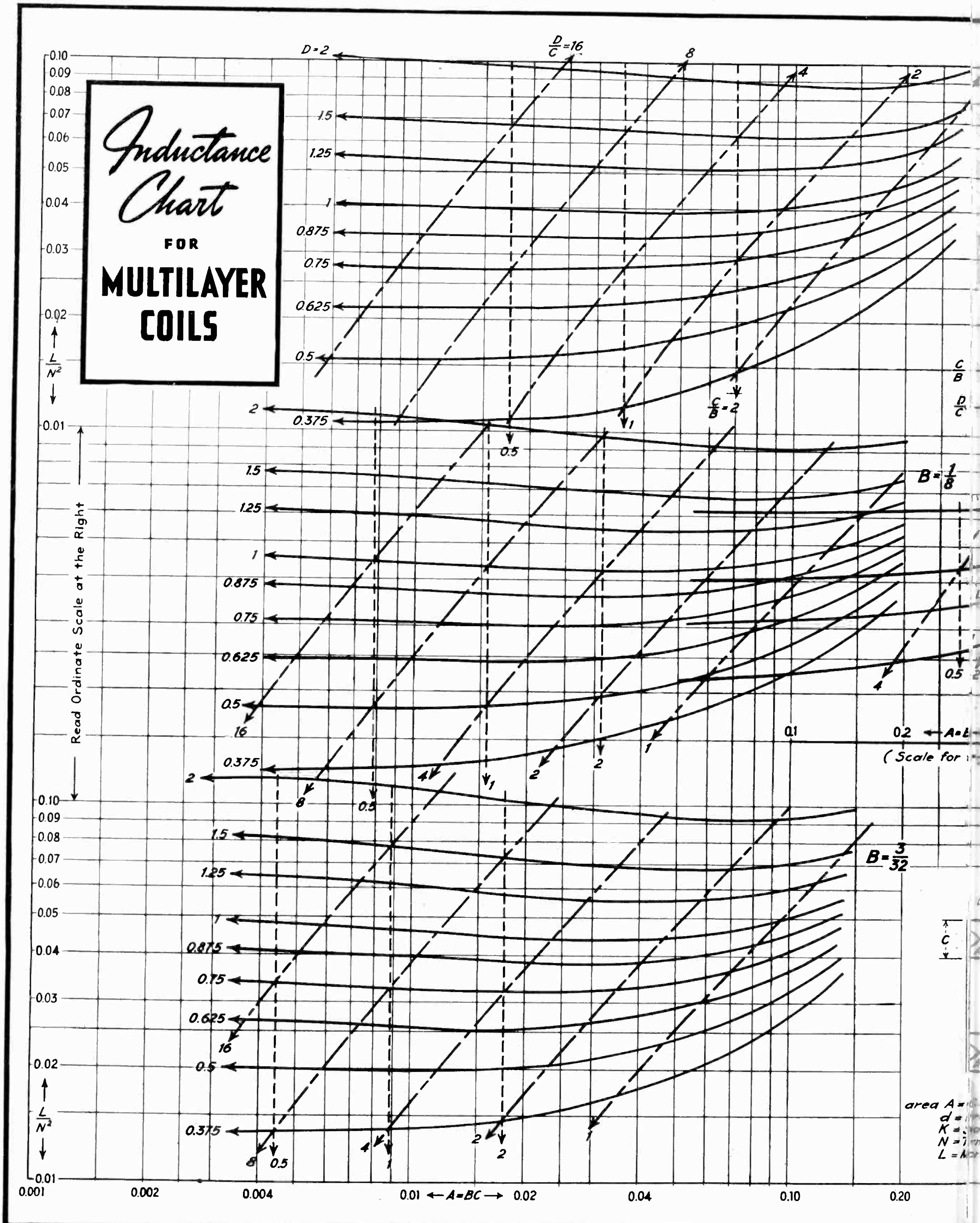
The chart applies to coils whose inner diameter, D, lies between 0.375 to 2 inches in coil widths of from 3/32 to $\frac{1}{4}$ inch, and from diameters of from 0.5 to 2 inches in coil widths of from $\frac{1}{4}$ to $\frac{1}{2}$ inch. One family of curves gives data for coils having values of D between 1 inch and 2 inches, for a coil width of $\frac{3}{4}$ inch.

The flexibility of this chart provides for the solution of several types of problems. The utility of the chart may be appreciated from the following table which shows the variety of coil calculations which may be made.

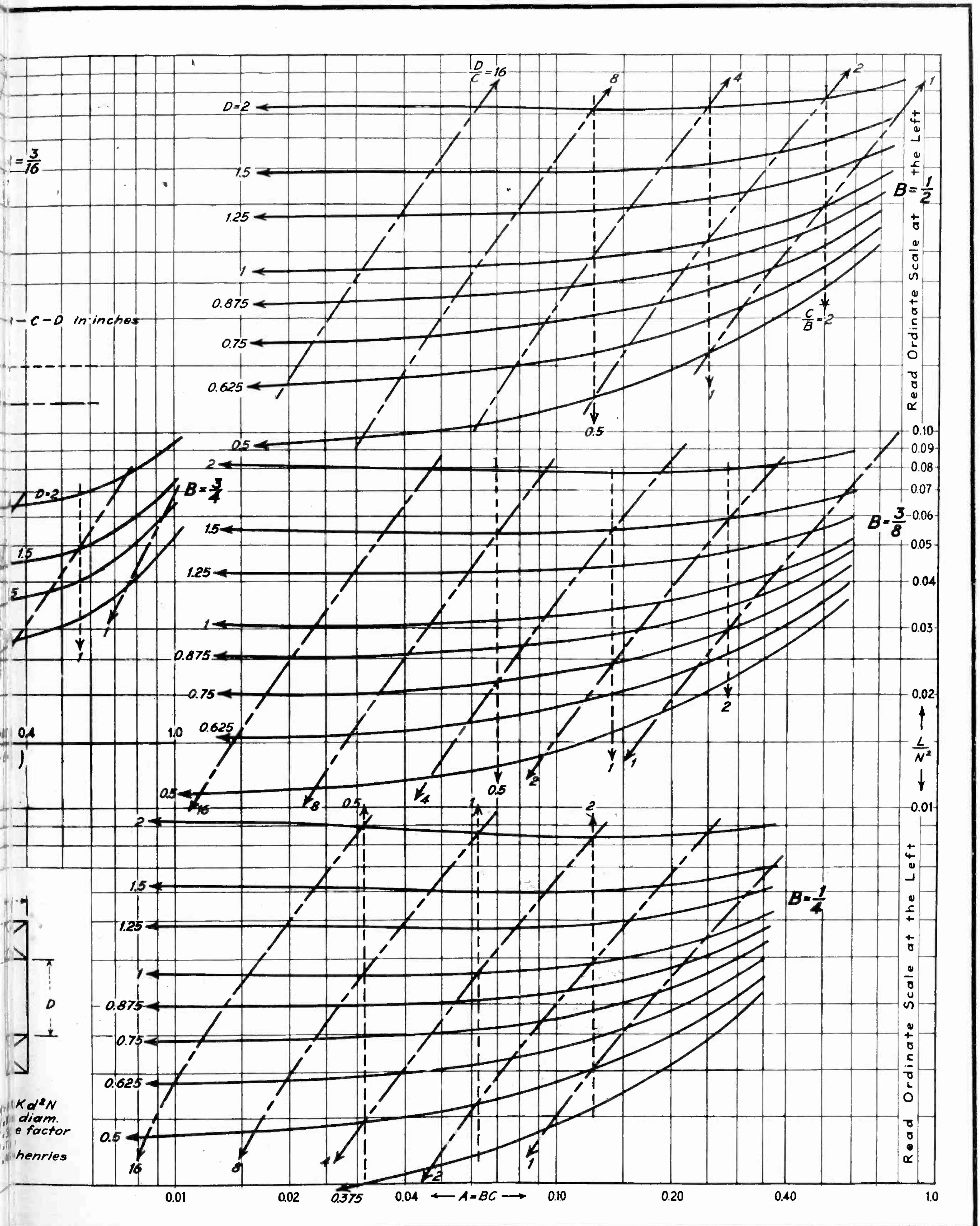
	Specified	Chosen	To be determined
1.	Inductance, coil diameter	wire size, coil or cam width	depth of winding, number of turns
2.	Inductance, overall diameter	coil or cam width, coil diameter, depth of winding, shape factors	wire size, number of turns
3.	Inductance, shape factors	wire size, coil diameter, depth of winding	coil or cam width, number of turns
4.	Inductance, shape factors, coil diameter, coil or cam width		number of turns, wire size

As examples of the use of this

* This chart is based on equations 157 and 158, pages 257 and 258 of "Radio Instruments and Measurements" *(Bureau of Standards, Circular No. 74)* which have been rearranged into a form more suitable for use in the design of a practical chart.



ELECTRONICS' REFERENCE SHEET



ELECTRONICS' REFERENCE SHEET

chart, several problems are given which will serve to illustrate the method of using the chart.

Problem 1. We wish to obtain a given inductance using a standard winding form. Assume the desired inductance is 8,000 microhenries, and the coil form has an inner diameter of 0.625 inch.

We begin by choosing a coil of square cross section (so that $C/B = 1$), a coil width $B = \frac{1}{4}$ inch, and select No. 35 enamelled S.S.C. wire for which the diameter is, $d = 0.0083$ inch. We may now determine that $C = \frac{1}{4}$ inch and $A = BC = \frac{1}{4} \times \frac{1}{4} = 0.0625$ square inch. Using the chart for the family of curves for which $B = \frac{1}{4}$, and remembering to use the left hand co-ordinates, we find that $L/N^2 = 0.021$.

We now have two methods of determining the number of turns. By using both determinations we may find that our chosen data is incompatible and may require some alteration. Using one method, we determine that $N^2 = L/0.021$ from which $N = 616$ turns. Using the other method which makes use of the equation $A = K\,d^2\,N$, we have, for $K = 1.25$ and $d = 0.0083$ that $N = [0.0625 / (1.25)(0.0083)^2] = 725$ turns. Since these two determinations do not check, either the wire must be made larger or the cross sectional area must be reduced. If we choose $A = [(616)(0.0625)/(725)] = 0.0535$ square inch, then $N = [(0.0535)/(1.25)(0.0083)^2] = 621$ turns. From the chart we determine that $L/N^2 = 0.0204$. Our coil will therefore consist of 621 turns of No. 35 enamelled S.S.C. wire whose depth of winding is $C = A/B = 0.0535/0.025 = 0.214$ inch, and $L = 0.0204 \times 621^2 = 7{,}900$ microhenries.

An actual coil had the following measured data: $B = 0.242$ inch, $D = \frac{5}{8}$ inch, and $C = 7/32$ inch $= 0.219$ inch. There were 610 turns of No. 35 enamelled S.S.C. wire, from which $K = 1.26$. The measured inductance was 8,050 microhenries.

Problem 2. We wish to obtain a given inductance with a coil winding of specified overall diameter. Assume the desired inductance to be 50,000 microhenries, and that overall coil diameter is to be 1.25 inch.

We chose a winding space such that $B = 0.5$ inch and $D = 0.625$ inch. Then $C = 0.5(1.25 - 0.625) = 0.3125$ inch, and $D/C = 2$. For these dimensions we determine from the chart that $L/N^2 = 0.017$, and consequently $N = (L/0.017)^{\frac{1}{2}} = (50{,}000/0.017)^{\frac{1}{2}} = 1715$ turns and $A = BC = 0.156$ square inch. We still have to determine the required wire size. From the equation $A = K\,d^2\,N$ we have that $d = (A/KN)^{\frac{1}{2}} = (0.156/1.25 \times 1715)^{\frac{1}{2}} = 0.0085$ inch. We select No. 35 enamelled S.S.C. wire from wire table data.

An actual coil measured as follows: $D = \frac{5}{8}$ inch, $B = 31/64$ inch, $C = 5/16$ inch, and $L = 50{,}000$ microhenries. There were 1700 turns of No. 35 S.S.C. wire.

Problem 3. We wish to obtain a given inductance and maintain optimum shape factors for good Q. In general, for good Q, C/B should be about 2. The ratio L/R_{dc} is optimum for $C/B = 1$, but the ratio L/R_{rf} is optimum for $C/B > 1$. D should be as large as may be consistent with practical requirements.

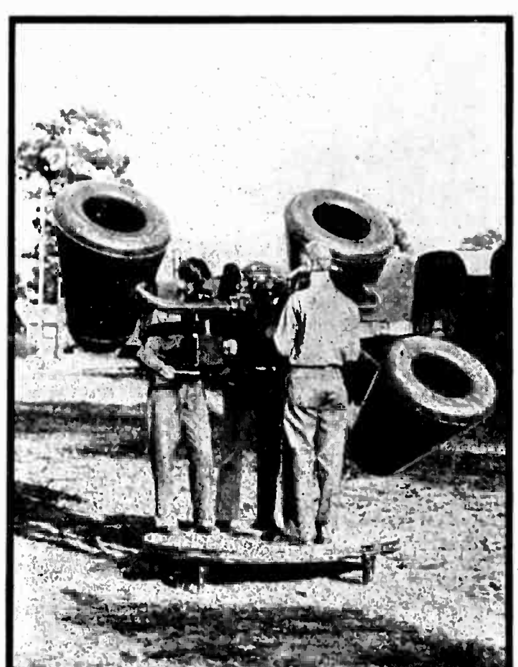
Let the desired inductance be 3,500 microhenries, and let $C/B = 2$ and $D/C = 2.5$. Choose a coil width, $B = \frac{1}{8}$ inch, so that $C = 2B = \frac{1}{4}$ inch, and $D = 2.5C = \frac{5}{8}$ inch. We shall be able to choose the wire size more readily after determining the required number of turns. From the chart we determine that $L/N^2 = 0.0247$ and $A = 0.0312$ square inch. Therefore, $N = (3500/0.0247)^{\frac{1}{2}} = 376$ turns, and $d = (A/KN)^{\frac{1}{2}}(0.0312/1.25 \times 376)^{\frac{1}{2}} = 0.0082$ inch. We may therefore use No. 35 enamelled S.S.C. wire.

An actual coil measured as follows: $B = 0.126$ inch, $A = 0.0316$ square inch, $D = \frac{5}{8}$ inch and $L = 3450$ microhenries. There were 386 turns of No. 35 enamelled S.S.C. wire.

Problem 4. We have a coil whose inductance and dimensions we can measure and we would like to duplicate it without damaging it. The measured data on the coil to be duplicated is found to be $D = 0.5$ inch, $B = 0.218$ inch, $C = 0.22$ inch and $L = 262$ microhenries. Consequently, $A = BC = 0.048$ square inch. Because the desired value of B does not appear on the chart interpolation becomes necessary. For $A = 0.048$ square inch, $D = 0.5$ inch and $B = 0.25$ inch we find that $L/N^2 = 0.0155$. For the case in which $A = 0.048$ square inch, $D = 0.5$ inch, and $B = 0.25$ inch, we find from the chart that $L/N^2 = 0.0177$. It now becomes necessary to interpolate to determine L/N^2 for the desired value of B. Interpolating, we have $L/N^2 = 0.0155 + [(0.25 - 0.218)/(0.25 - 0.187)](0.0177 - 0.0155) = 0.0167$. This gives $N = (262/0.0167)^{\frac{1}{2}} = 126$ turns. The wire size is $d = (A/KN)^{\frac{1}{2}} = (0.048/1.25 \times 124)^{\frac{1}{2}} = 0.0181$ inch, so that No. 31 enamelled D.C.C. wire may be used. The actual number of turns on the measured coil was 125.

From the character of the curves on the chart it will be noted that this method of determining the number of turns on an unknown coil is considerably more accurate than any based on dimensional measurements, since it is largely dependent on the electrical measurement of inductance and the accuracy of the chart. The dimensional measurements determine the value of A which, as previously mentioned, is non-critical in determining the inductance per squared turn ratio. Furthermore, N is proportional to the square root of the determined data. On the other hand, the determination of turns from the measurements of the coil dimensions and wire diameter through the equation $N = (A/Kd^2)$ involves such variables as space factor and tolerance in wire diameter as well as the difficulty of measuring accurately the dimensions B and C.

IMPROVED AIRCAFT DETECTION



This new sound detector of the U.S. Army anti-aircraft service employs three short horns, instead of the usual four long ones, and each horn is made of balsa wood with cellulose acetate coating. The new design has a much higher signal-to interference ratio than the old

TUBES AT WORK

Resistors at Video Frequencies

By A. W. Barber

High definition television has, in the space of two or three years, extended the need for broad band amplifiers from kilocycles to megacycles.

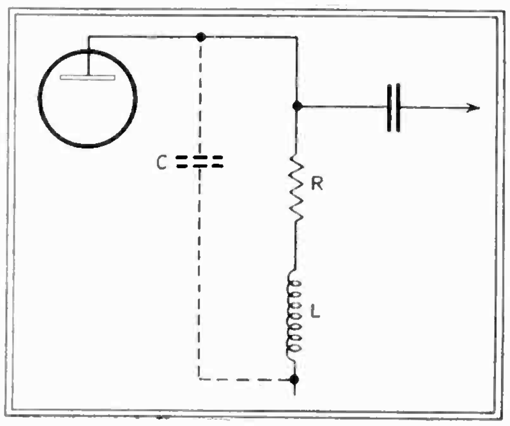


Fig. 1.—Basic circuit of series-compensated video amplifier stage.

In designing and building these wide range amplifiers the problem may be divided into two parts. First, theoretical circuit design must be developed to meet the new requirements. Second, these theoretical circuits must be transformed into practical amplifiers. In transforming a theoretical circuit into a practical model a knowledge of the characteristics of circuit components is necessary. At five Mc the inductance of condensers, the inductance and capacity of resistors and the distributed capacity of inductances must be more carefully studied than in the past.

In Fig. 1 a common type of video amplifier compensated plate circuit is shown. The low and middle frequency gain of the stage is determined by the value of R. The shunting effect of the tube and circuit capacity C at the high frequency end of the range is compensated by L. It has been shown that the stage gain may be maintained flat to a frequency f if the following relation is satisfied: $R = 2L2\pi f = 1/C2\pi f$.

A non-inductive resistor may be used for R with the proper inductance L inserted in the form of a coil. A more economical design results if a wire wound resistor having the proper inductance is used to replace R and L. Thus a study of available resistors becomes useful.

One way to find the resistance performance characteristics is to place it in an actual tube plate circuit and measure gain at various frequencies. This procedure, however, gives the effect of a particular and more or less unknown shunt capacity at the same time. If all shunt capacity is eliminated the characteristics of the resistor alone may be studied. A circuit for measuring resistor impedance without the effects of shunting capacity is shown in Fig. 2. The resistor to be examined is placed in shunt with a tuned circuit L_1 C_1 connected in the plate circuit of a vacuum tube. If this circuit is tuned to the measurement frequency before the unknown resistor is placed in shunt the effective plate load is equal to the impedance of resistor R L C in parallel with the tuned circuit impedance at resonance. If a high Q circuit is used with a nominal value of resistance R L C the gain may be assumed to be determined entirely by the resistor impedance.

The circuit of Fig. 2 was used to investigate the impedance characteristics of several types of resistors all having a d-c resistance of 1000 ohms. The measured impedances at frequencies from one to five Mc are plotted in Fig. 3. Resistor "a" was a metalized type resistor and showed a negligable impedance change from its d-c value up to five Mc. Resistor "b" was a ten watt wire wound resistor and showed a rise in impedance indicating an inductance of the proper value to compensate 32 $\mu\mu$f shunt capacity up to five Mc. Two different makes of resistor were found to have this characteristic. Resistor "c" was a wire wound resistor of the same general appearance as resistor "b" but its large rise in impedance indicates a much larger inductance. It would be suitable to use in compensating a capacity of 100 $\mu\mu$f shunt capacity up to one and one-half Mc. Resistor "d" was a pi-wound "non-inductive" resistor and showed a still larger inductance.

Using the same set-up of Fig. 2 the impedance measurements were repeated

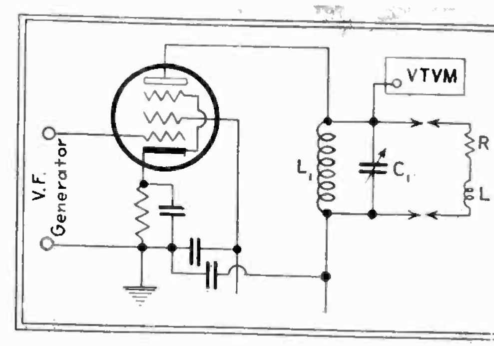
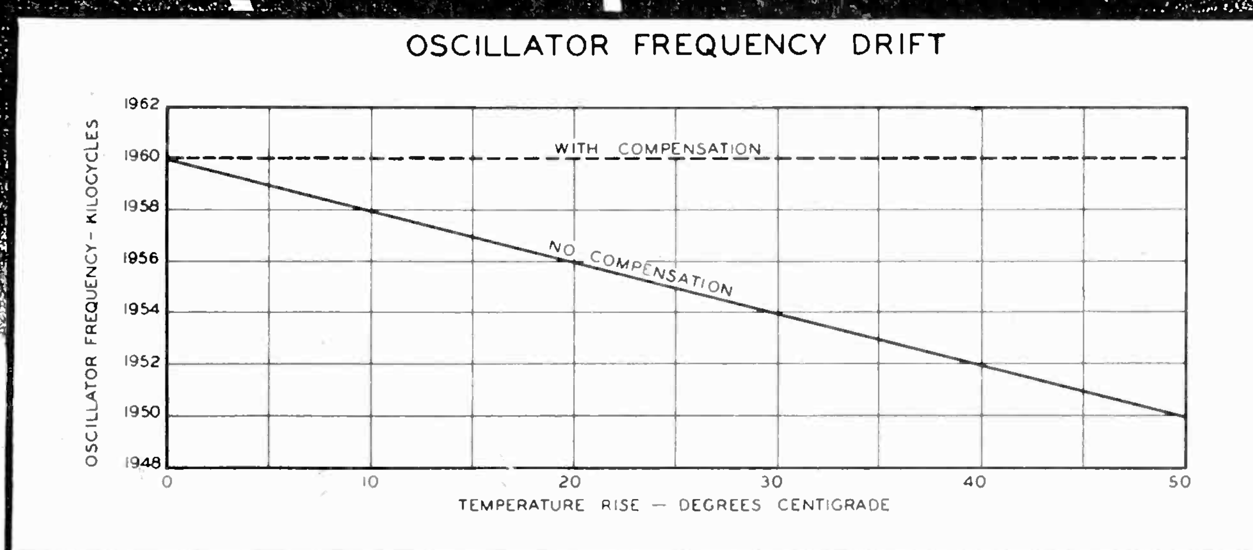
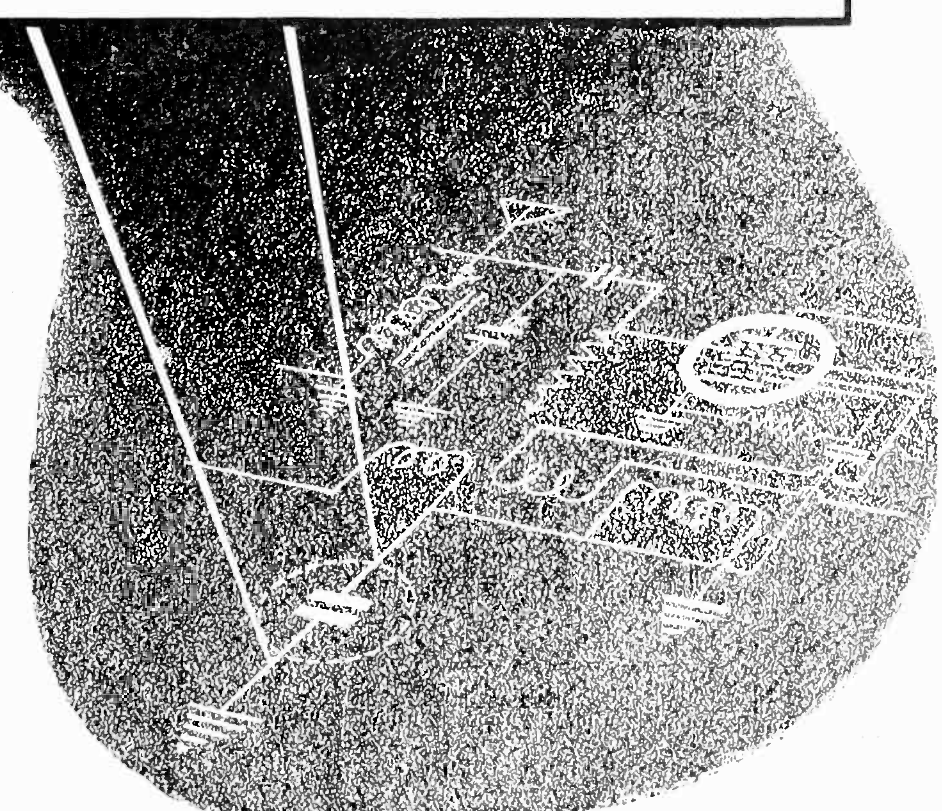


Fig. 2—Method of measuring resistances at video frequencies.

FACSIMILE RECEIVER FOR NEWSPAPERS

Facsimile receiving equipment used during the inauguration of regular broadcasting on ultra-high frequencies from W9XYZ, operated by the St. Louis Post Dispatch. The recorder contains rolls of paper and carbon tissue which pass over a revolving metal cylinder from which a projecting stylus produces an image. Copy is in black and white, printed on one side of the sheet. The recorder is automatically timed to begin operation at a predetermined instant



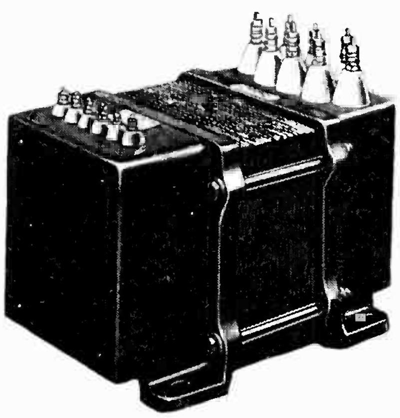


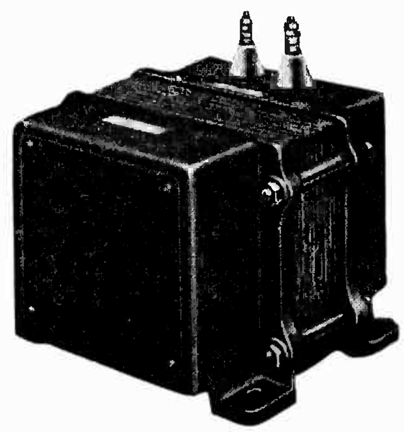
Centralab fixed capacitors consist of a thin wall ceramic tube spacing two tubular condenser plates, electro-plated on the ceramic. Capacitance remains permanent under all life and aging tests. Centralab capacitors do not depend upon pressure fit for contact at any point, but have a positive soldered joint between plates and wire leads. All capacitors are vacuum impregnated with wax and coated with a moisture-proof film of low power factor resin.

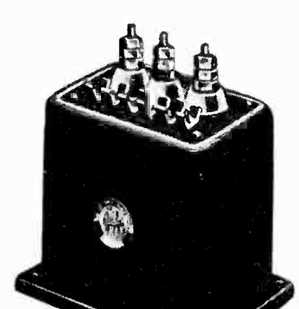
A SPECIAL BULLETIN SHOWING ENGINEERING DATA AVAILABLE ON REQUEST. SPECIFY BULLETIN 630

Centralab

Division of Globe Union
Milwaukee, Wisc.







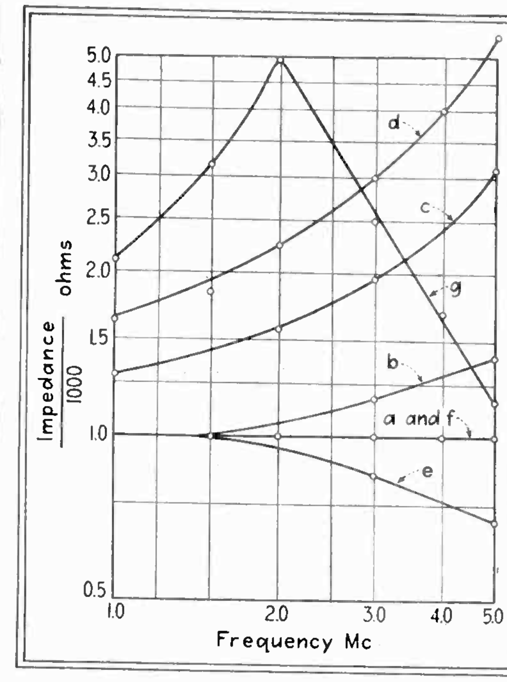
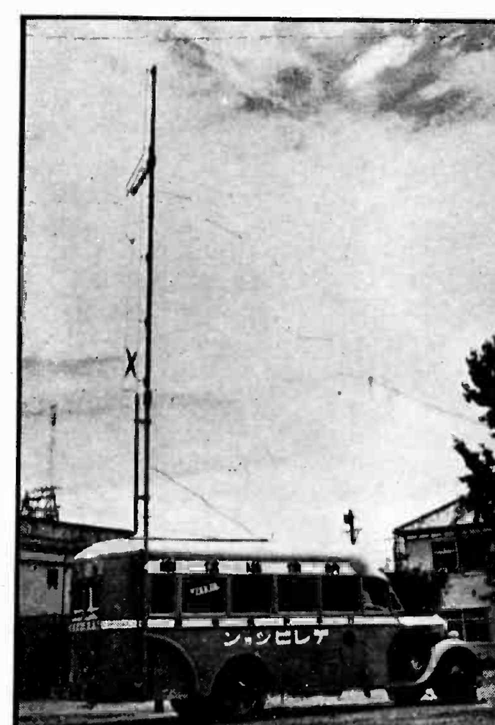


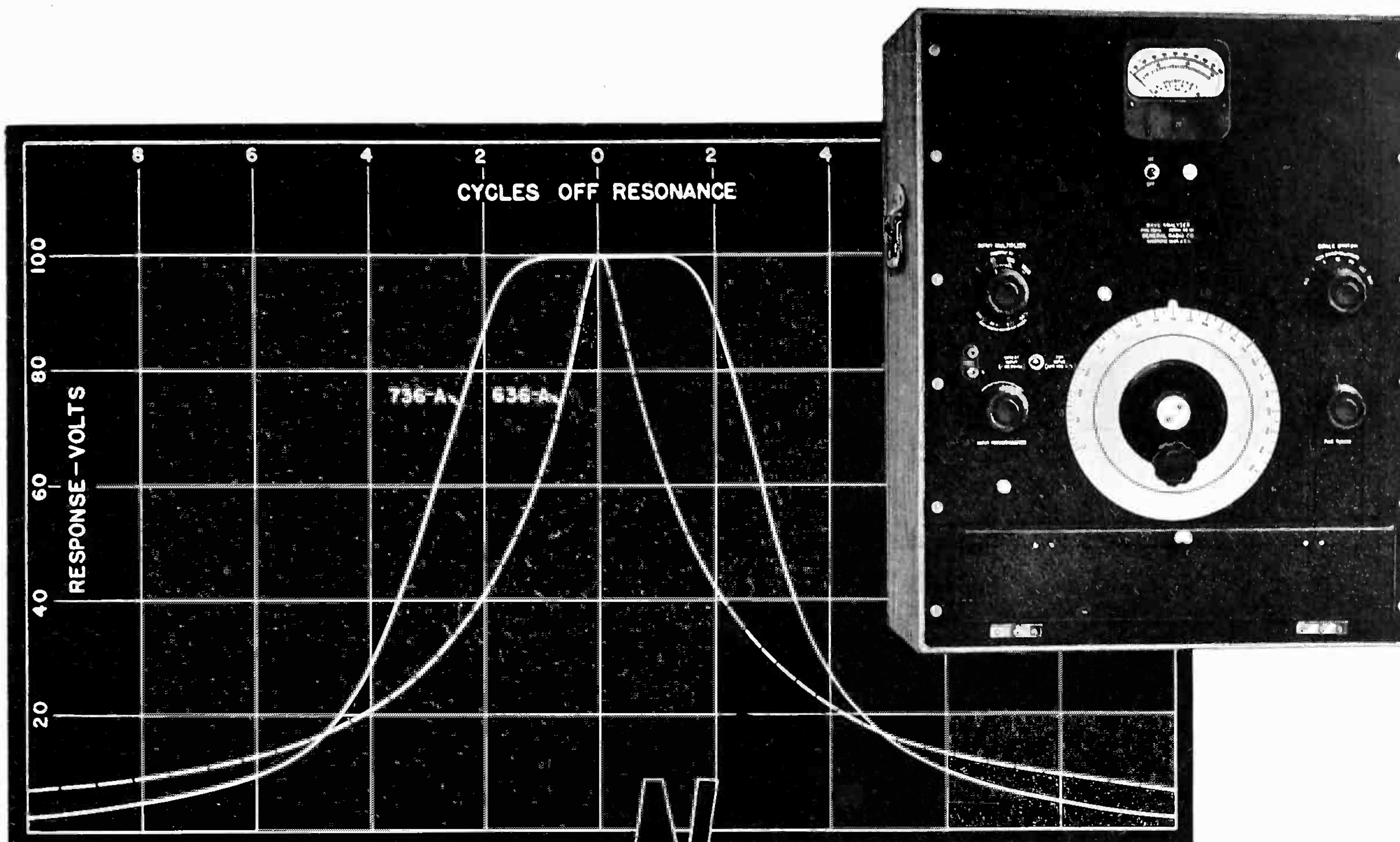
Fig. 3—Impedance vs. frequency curves of different resistors

using a shunt capacity of 32 $\mu\mu$f in each case. As would be expected resistor "a" which showed a negligable inductive component when shunted by the capacity showed a three db drop at five Mc. Resistor "b" which showed a three db rise when measured alone indicating about sixteen microhenrys inductance when shunted showed a flat impedance to five Mc. Actually two different makes of resistor yielded a flat characteristic when shunted and hence offer a practical saving in cost and space over the

TELEVISION IN JAPAN



A 20-watt video transmitter is mounted in this Japanese mobile television unit, used to transmit news events to the main station. The all-electronic system, similar to that employed in America and Europe, is used



NEW WAVE ANALYZER

THE NEW Type 736-A Wave Analyzer provides the simplest and most accurate method for making analyses of harmonic distortion in audio-frequency equipment, broadcasting receivers and transmitters, telephones for public-address systems, oscillators and vacuum-tube circuits of all types; in electrical power systems and electrical machinery.

The new analyzer has the following mechanical and electrical improvements which contribute to its increased sensitivity, improved stability and more convenient operation:

- CRITICAL TUNING UNNECESSARY: flat-top tuning characteristic 4 cycles wide (see curve)
- IMPROVED SELECTIVITY: new 3-crystal filter increases discrimination against unwanted voltage. Attenuation at 60 cycles from resonance is 75 db (0.02%)
- EASIER OPERATION: improved calibration circuit makes precise balancing unnecessary and speeds up measurements
- EXTENDED VOLTAGE RANGE: 300 microvolts to 300 volts, full scale, with 1 megohm input impedance
- INCREASED STABILITY: all components protected from effects of humidity. Oscillator and amplifier stability improved greatly
- A-C OPERATION: the hum voltage less than 50 microvolts
- NO EXTERNAL MAGNETIC PICK-UP: balanced modulator is fed by a phase-inverter tube instead of a transformer

TYPE 736-A WAVE ANALYZER $640.00

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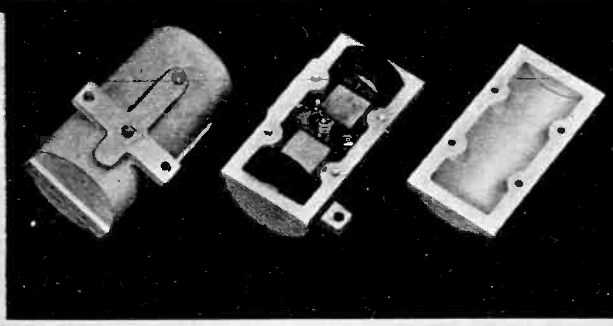
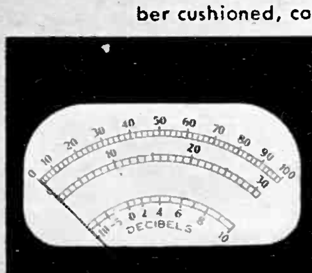
GENERAL RADIO COMPANY

Cambridge, Massachusetts

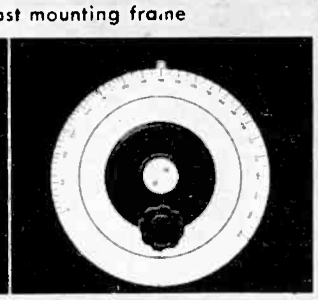
BRANCHES: New York and Los Angeles



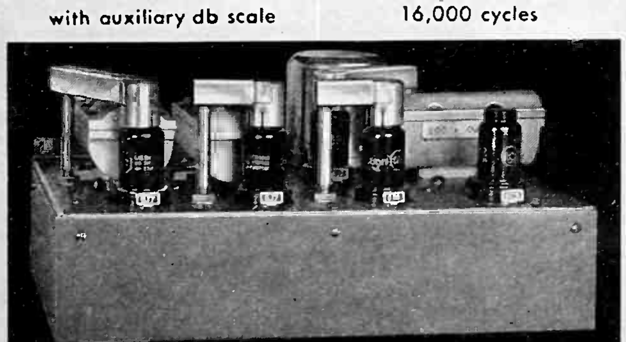
Hermetically sealed, 3-electrode quartz crystal in rubber cushioned, cast mounting frame



Illuminated linear meter with auxiliary db scale



Direct reading from zero to 16,000 cycles



Low-impedance, stable, aperiodic amplifier of moisture-proof construction

PRECISION ELECTRICAL LABORATORY APPARATUS

A CRYSTAL IN A THERMOS BOTTLE

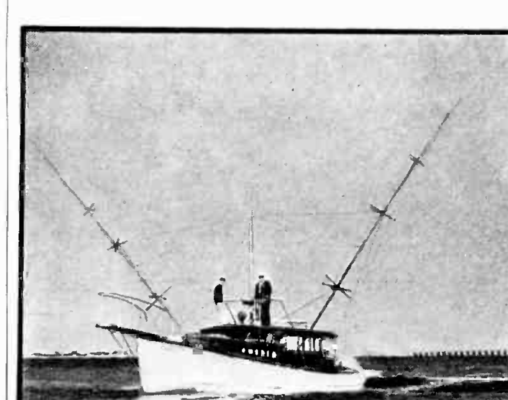
This tube contains two walls and encloses a quartz crystal used for frequency control. Both sections of the tube are evacuated, providing protection against temperature changes similar to that of a Dewar vessel. One crystal terminal is taken through the glass, the other through the socket

use of a non-inductive resistor plus a compensating coil. Resistor "d" which showed the largest inductance when measured alone showed a large peak in impedance at two Mc as shown by curve "g" in Fig. 3.

The effective shunt capacity of the sample resistors measured was of the order of one micro-microfarad. Since this represents a quadrature component of about 32,000 ohms it can be neglected in most applications.

An experimental resistor wound with two oppositely directed layers of wire placed turn upon turn unexpectedly showed a much larger inductance than a similarly wound coil of copper wire. This was found to be due to the use of inductive resistance wire. Winding the resistor of non-inductive resistance wire reduced the inductance of a 1000 ohm resistor from about 80 microhenrys to about two microhenrys.

FISH-POLE ANTENNA (MARINE VERSION)



By stringing a cage antenna on each of the two outrigger fishpoles of this pleasure craft, the range of the single-frequency transmitter on board was more than doubled

Aircraft Radio

(*Continued from page 14*)

at 75 Mc. In all, the transmitter employs 13 tubes, including power supply. The output of a 4.6875 Mc crystal is quadrupled and doubled twice to 75 Mc, finally driving two 304-B tubes to 100 watts, at 60 per cent efficiency. Two 838 tubes are used as modulators, at 3000 cps.

The radiating system employed to produce the fan-type wedge of signal consists of four half-wave sections, placed end-to-end and fed in phase. The accompanying diagram shows the method of in-phase feeding with a single transmission line. By including two hair-pin loops, each one-half wavelength long, the currents in all radiating sections are caused to flow in the same direction. The radiating system is supported one-quarter wavelength above a metal-screen counterpoise measuring 20 by 40 feet. The purpose of the counterpoise is to avoid changes in the radiation pattern as the condition of the ground changes with the seasons (weeds and snow are serious offenders).

Flight tests over the beacon indicate that the wedge of signal extends well into the stratosphere, that its effective thickness (measuring in the direction of the route) is 2.5 miles at 3,000 feet altitude, 4 miles at 11,000 feet. The width of the wedge varies from 10 to 15 miles in the same range of altitude. The beacons are to be placed at strategic intervals along the radio-range beacon courses, and are used to indicate the ship's position along the airline right-of-way.

While these developments have been in progress, the aircraft radio equipment manufacturers have been busy improving more conventional apparatus. Weight continues to decrease and performance to increase. The Douglas DC-4, largest transport ship, has been equipped with a 250 watt main transmitter, and with three receivers, including a 75 Mc marker receiver. Remote tuning has been applied to airport transmitters, and to airplane transmitters as well. A 15 watt transmitter for use on the communication frequencies (3105, 3120, and 6210 kc), weighing only 22 pounds, has been announced. Finally, facsimile transmissions to aircraft have been undertaken by the Finch organization.

THE ELECTRON ART

Summaries of articles on methods of producing sub-atomic particles, design of superheterodyne oscillator circuit, studies of thoriated tungsten, and a simplified method of treating electrical networks for sound recording in the month's news

Recent Progress in the Development of High Voltages

A CRITICAL REVIEW of the recent progress in the development of extremely high voltages is contained in an article "Production of High Energy Particles" by W. H. Wells, which appears in the November issue of the *Journal of Applied Physics*. This article describes the various types of high voltage generating equipment which have recently been constructed for carrying on research programs dealing with the structure of the atom. High voltage generators such as those used at the Westinghouse Research laboratories, the Department of Terrestrial Magnetism, Carnegie Institution of Washington, the Cavendish Laboratories, the University of Michigan, the University of Wisconsin, and the Massachusetts Institute of Technology are described.

The results which have been obtained with various methods of producing extremely high voltages are reviewed and the author concludes that the methods of accelerating charged particles of high energy which have received the most successful developments for nuclear transmutations are those of direct high voltage by means of belt machines as developed by Van de Graaff and the cyclotron method due to E. O. Lawrence.

Design and Technique of the Cyclotron

A DESCRIPTION of the method and application of the cyclotron as developed by E. O. Lawrence and his associates at the Radiation Laboratory, Berkeley, Calif. is given in the November issue of the *Journal of Applied Physics*. Writing under the title, "Present Day Design and Technique of the Cyclotron," Franz N. Kurie gives an analysis and summary of methods of "atom-smashing" through the use of intense magnetic fields as developed in the cyclotron. This paper is a companion to "Production of High Energy Particles" by W. H. Wells appearing in the same issue of *J. A. P.*

The atom-smasher is simply a machine for giving such high velocity to small sub-atomic particles (such as the proton, deuteron, neutron and alpha particles) that atoms may be penetrated by these sub-atomic particles. By measuring the energies of these projectiles and the energies of the fragments of the smashed atoms together with the energies of any secondary disturbances, one gets the primary facts out of which an understanding of the structure of atomic nuclei may be adduced.

The typical accelerating machine will consist of some sort of ionized particles, some disposition of electric fields to accelerate them, and chambers for studying the effects produced.

The theory of the cyclotron is given as well as some of the constructional and design details. The results of a number of workers in this field are reviewed, and equipment which has been constructed at various research laboratories is described. In conclusion the author indicates several of the possible benefits which may be expected to accrue from the apparently impractical research program of disintegrating those particles which are among the smallest of which matter is composed.

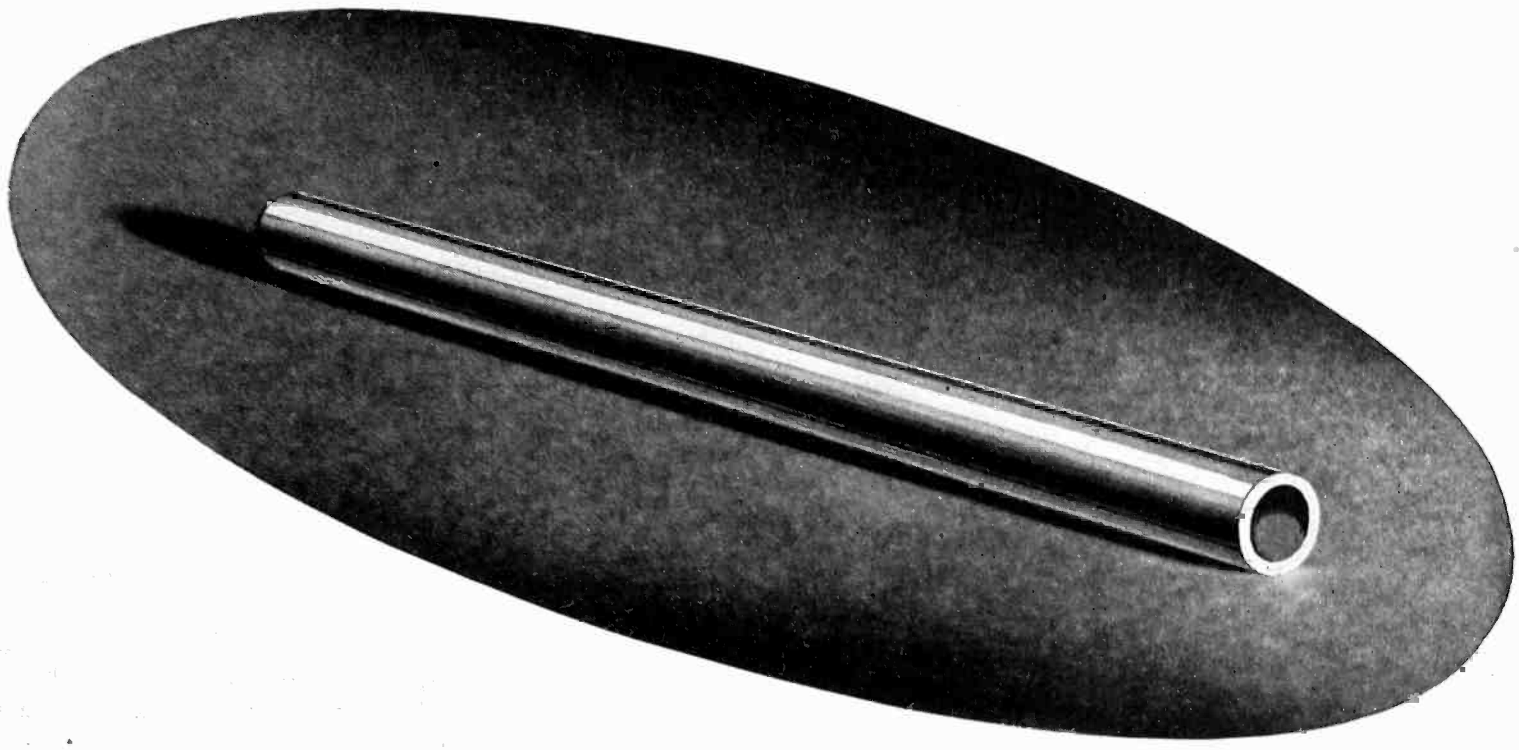
B. B. C. TELEVISES FULL LENGTH STAGE PLAY

A full length stage play, "When We Are Married" was recently televised by the B. B. C. from St. Martin's Theater for the benefit of London television enthusiasts. Two cameras were set up in the first row of the theater, one at the center and the other at the left of the stage as shown here. The characters shown on the stage are, in the usual left to right order, Ernest Butcher, Raymond Huntley, Lloyd Pearson, and Richard Warner

Simplified Method of Treating Networks

A SHORT, concise article on the necessity for their use, application, and design of electrical networks for sound recording is given by F. L. Hopper in the November issue of the *Journal of the Society of Motion Pictures Engineers*, in an article entitled "Electrical Networks for Sound Recording." Particular emphasis is placed upon the constant resistance type of structure.

In sound recording a number of factors exist that necessitate certain modifications and limitations of the uniform response-frequency characteristics of the equipment in order to achieve pleasing results. In brief, these factors are as follows: (1) the effects due to the acoustical conditions surrounding the point of pick-up, (2) the response characteristic of the microphone, (3) the properties of the modulating device in noise reduction systems, (4) in recording, the ability to compensate for defects occurring in recording, and the introduction of characteristics providing a dramatic effect. It is possible to obtain alteration of all of these characteristics through the use of electrical networks having the desired response-frequency characteristics. The particular network for a given condition depends upon the required insertion loss, the impedance of the circuit in which it is to operate, and the reaction of the impedance characteristics of the network upon the frequency response of the equipment associated with it. While the design of many filters and networks for obtaining desired response-fre-



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quency characteristics are covered in available reference work, the author presents a simplified means of determining design data of the bridge-*T* network, of the constant resistance type.

The article gives curves showing the insertion loss for the network, plotted against the impedance across the series arms of the *T* when used in the 500 ohm circuit. The characteristics of the impedance, Z_{11}, across the arms of the *T*, as well as of the impedance Z_{a}, in series with the shunt element of the *T*, determine the frequency-response characteristics of the network. The characteristics of the impedance, Z_{11}, may be determined for a 500 ohm line by means of a graphical chart which is shown. A supplementary table or equalizer chart, gives the relationship between the two impedances for a given type of frequency-response characteristic.

An appendix is included in which the essential equations are derived, and examples are given of the methods by which attenuating networks or equalizers for recording may be designed.

Design of Oscillator Circuit for Superheterodyne Receivers

AN UNUSUALLY THOROUGH discussion of the method of designing the *L* and *C* constants for the oscillator circuits of superheterodyne receivers is contained in the November 1938 issue of the *Philips Setmakers' Bulletin*, published by the Philips' Gloeilampenfabriken, Eindhoven, Holland.

For designing a radio receiver of the superheterodyne type, and having decided upon the intermediate frequency and wave length ranges to be covered, the question arises as to how the various parts of the oscillator circuit should be dimensioned. While much has been written on the problem of the correct design of the oscillator circuit in the determination of the *LC* constants, no general rule has been given for calculating these values.

If we are given an oscillator tuned circuit of the type shown in Fig. 1,

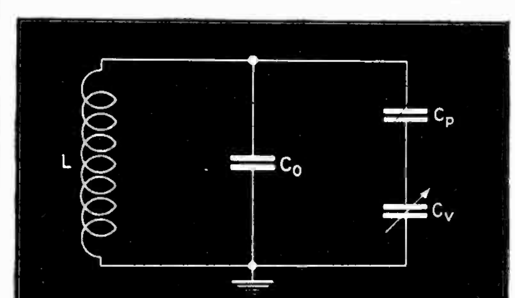
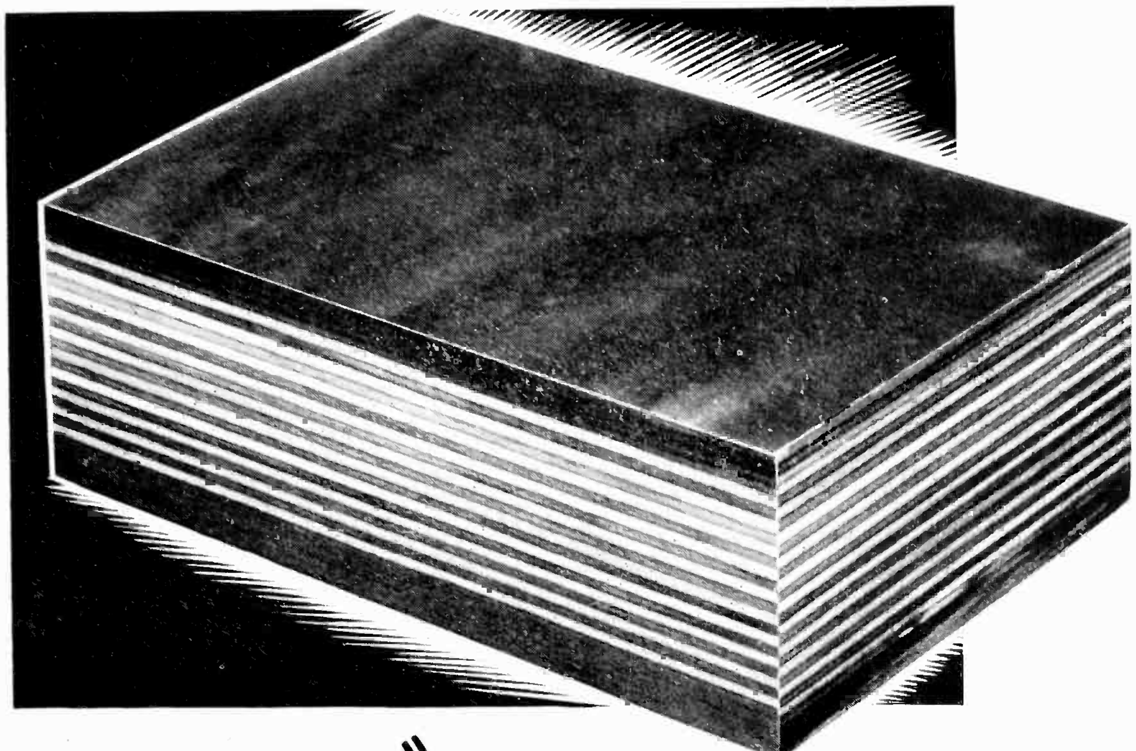


Fig. 1—Schematic circuit of oscillator in superheterodyne receivers for which analysis is made

consisting of an inductance, *L*, a tuning condenser, C_v, a padding condenser, C_p, and a shunt capacity, C_o, the problem is to design the *LC* constants of the circuit so that the natural frequency in every position of C_v is higher than that of the preceding circuit by a definite amount equal to the intermediate frequency.



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Considered in its exact form, the problem is insoluble. The practical approach thus is to design the oscillator circuit so that throughout its entire tuning range, the deviation from the desired value will be a minimum. That is, the difference in frequency between the oscillator circuit and the input circuit should be a constant equal to the intermediate frequency, but deviations from this value should be a minimum. The deficit or excess to be tolerated, which may, for instance, be plotted against the frequency of the preceding circuit, will give what is termed as the "padding curve," such as that in Fig. 2. The similarity of

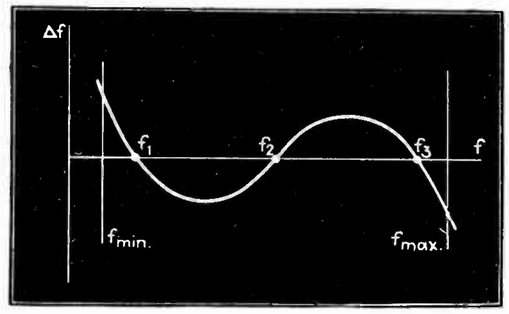

Fig. 2—Padding curve of superheterodyne circuit resembles that of a cubic equation

this curve with the third degree curve suggests that a cubic equation may be used for the analysis of circuit constants. It has been determined that the third degree curve best fulfilling the desired condition is of the form, $y = x^3 - 3/4x$, where y is the frequency deviation, and x is the frequency to which the receiver is to be tuned, taken so that the position $x = 0$ corresponds to the arithmetic mean of the frequency band. For zero frequency deviation ($y = 0$) the corresponding frequencies are $x = 0$, $x = +\sqrt{3}/2$, and $x = -\sqrt{3}/2$ as measured from the mid-frequency. Thus one point will be in the middle of the frequency band to which the receiver is tuned, and the two others are in symetrical positions on either side of this point, so that their distance from the mid-frequency is $3(f_{max} - f_{min})/4$. The corresponding oscillator frequencies can then be determined by adding to the frequencies thus determined, the intermediate frequency (455 kc). Let the three points of zero frequency deviations be designated by the symbol f_1, f_2, f_3.

A graphical method of determing the constants of the three condensers, C_o, C_v, and C_p, is given. In this method, a plot is made of suitable values of C_o, C_v, and C_p. The magnitude of C_o is plotted below the horizontal axis, while the other two condensers are plotted above the axis, the two scales being separated by one another at some convenient distance. A transparent fan-shaped scale or plot on which are plotted in proper proportions the values $1/f_1^2$, $1/f_2^2$, $1/f_3^2$, may then be super-imposed upon the capacitance chart, by properly aligning a transparent over-lay sheet with the capacitance chart, the circuit design may be quite rapidly determined.

The theory of these design charts is covered in the original article.

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Makers of instruments for radio transmission and reception of sound, code messages and facsimile reproduction. Makers of instruments for the recording of sound on records and on motion picture film. Creators of countless radio devices vital to science, industry, medicine, telephony, and public safety.

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RCA . . . creator of a world-wide radio communications system with direct circuits between the United States and 43 foreign countries, and with ships at sea . . . a message service with the speed of lightning.

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RCA . . . truly American, owned by a quarter of a million stockholders in 48 states.

RCA . . . 19 years a name across the sky . . . 19 years of service to all the world.

Listen to the "MAGIC KEY" every Sunday, 2 to 3 P. M., E. S. T., on the NBC Blue Network.

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RCA Institutes, Inc. National Broadcasting Company R.C.A. Communications, Inc.

Study of Thoriated Tungsten

According to an article, "Electron Microscope Studies of Thoriated Tungsten" by Arthur J. Ahearn and Joseph A. Becker, in the September 15 issue of the *Physical Review*, many past experiments have shown the thermionic activity of a thoriated tungsten filament is determined by the concentration of thorium on its surface. This concentration is in turn determined by the rate of arrival and rate of evaporation of thorium. Studies have been made of the arrival and evaporation of thorium through the use of an electron microscope used to obtain electron images of thoriated tungsten ribbons. A comparison of the electron images with photomicrographs shows that the active and inactive patches composing an electron image agree in size, shape and number with the exposed grains of the tungsten. The electron microscope shows that thorium comes to the surface in eruptions at a relatively small number of points which are located at random. From a comparison of photomicrographs showing thoria globules and electron images of thorium eruptions, it is deduced that all the thorium in a globule comes to the surface when an eruption occurs. Patches such as a high temperature flash and sudden heating and cooling of the filament affect the frequency of eruptions. Thorium eruptions are the only observed manner in which thorium arrives at the filament surface. They are repeatedly observed in the earlier stages of thoriation. Eruptions are not observed in the later stages of thoriation where conditions are unfavorable for their observers. During the process of thoriating a filament, the relative emissions from different grains of the cathode change by substantial amounts. In many cases this change is sufficiently great so that the relative emissions of various grains are reversed.

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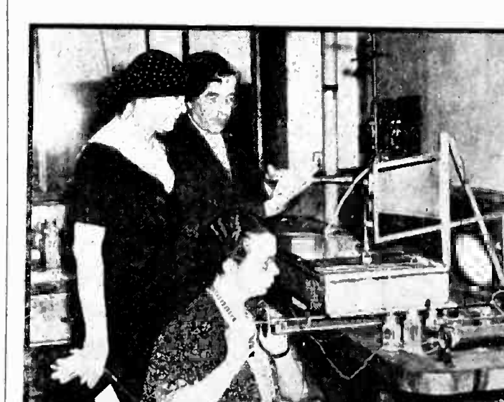
MOLECULAR FILMS



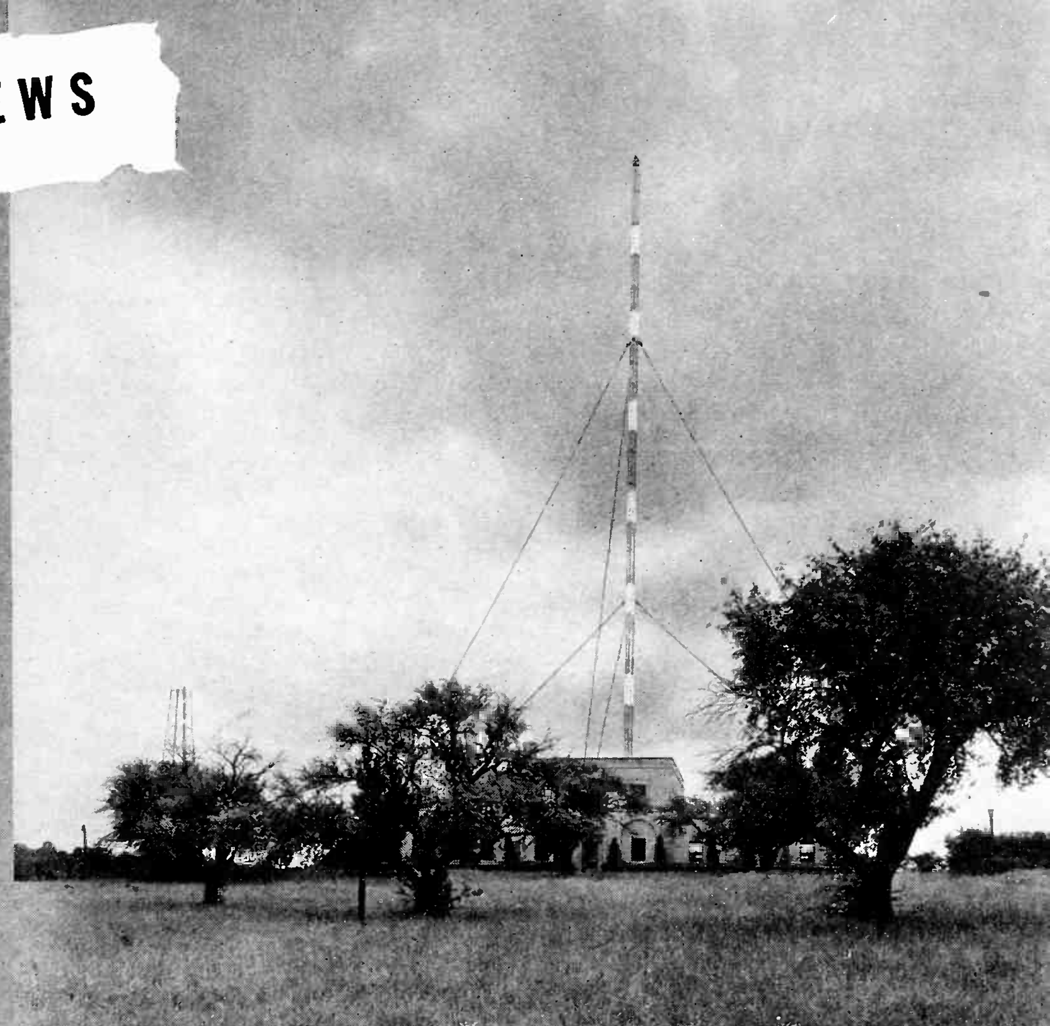
Irving Langmuir and Dr. Katherine Blodgett (seated) demonstrate their technique of forming molecular layers of oil on water to Dorothy Thompson, the political writer who has recently turned to popularizing scientific achievements

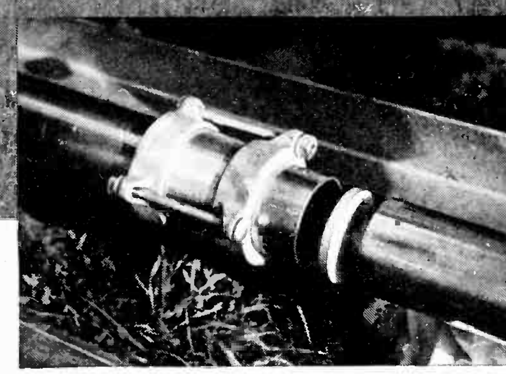
TRANSMISSION LINE NEWS

GAS-FILLED ALUMINUM COAXIAL CONDUCTOR

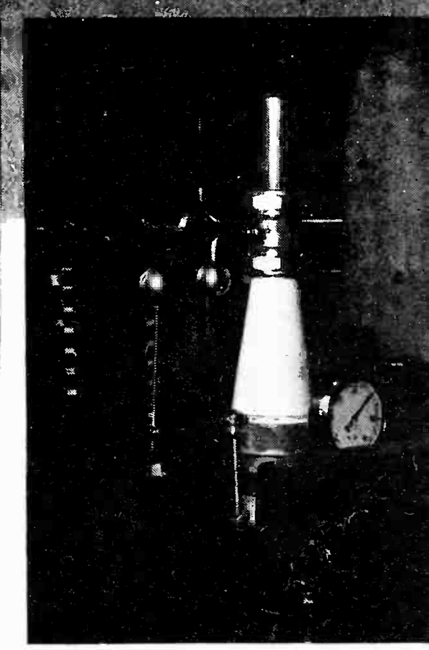
made by ISOLANTITE

installed at WTAM



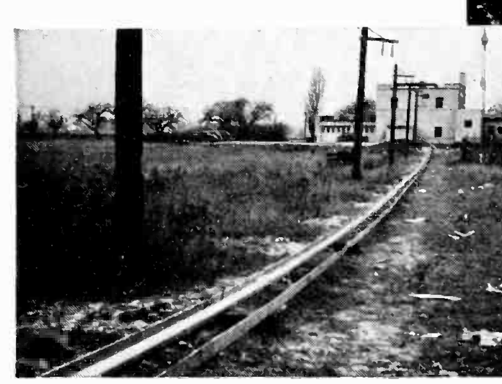


Above: Locking insulator located at center of line allows two-way expansion. Solderless connectors provide gas-tight joints.



Right: Fittings for the line include gas-tight Isolantite end seal equipped with lightning protection gaps and gage for checking gas pressure.

Below, right: A simple tightening operation with a wrench seals the joints in the line against leakage of gas.



Below: A view of the installed line leading from the transmitter to WTAM's tuning tower.

ISOLANTITE INC. pioneers again with the introduction of gas-filled aluminum coaxial transmission line for the new 470-foot vertical radiator at Station WTAM, Cleveland.

Light weight and low cost feature this radically new development in transmission line design, while life factor and electrical properties are comparable to those of copper. *Solderless* connectors make gas-tight joints of high tensile strength by a simple process of tightening bolts. Iso-Q* low-loss ceramic insulators, shaped to conform with the electrical field, and shielded to eliminate air gap stresses, provide the ultimate in safety and efficiency.

The differential expansion or contraction between the inner and outer tubes is halved by locking the two tubes securely with respect to each other at the middle of the line, so that expansion takes place in both directions from the center point.

Every detail of this new aluminum line is engineered with the same skill that has made Isolantite copper transmission line the choice of more than 100 broadcasting stations throughout the country. Write for information on aluminum and copper transmission lines for broadcast, police radio, airway beacon, and communications equipment.

SOLD ONLY THROUGH GRAYBAR ELECTRIC CO. AND MANUFACTURERS OF TRANSMITTING EQUIPMENT.

* Registered trade-name for the new lower loss products of Isolantite Inc.

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Shot Noise in Diodes

To THE important contribution of the effect of space charge and shot noise in electron tubes made by Schottky, Spenke, and others, may be added the article by A. J. Rack, who writes on "Effects of Space Charge and Transit Time on the Shot Noise in Diodes", in the October issue of the *Bell System Technical Journal.*

The paper is too long and mathematical to review in any detail here. According to the author's summary, the theoretical analysis of the effect of space charge upon the "shot noise" in a planar diode shows that for practically all operating conditions, the tube noise is equivalent to the thermal resistance noise of the plate resistance and 0.644 times the cathode temperature. Noise in diodes other than planer shape is discussed and it is concluded that the same relations hold. It is shown the transit time produces the same high frequency modification for both the thermal and shot tube noise, and that the tube noise is decreased by transit time.

For convenience the paper is divided into three parts. In the first section is given an exact mathematical treatment of the tube noise at low frequency in a parallel plane diode for any degree of space charge. A discussion of the final tube noise equation obtained by this analysis, and the extension of these results for the planar diode to any other shape diode is given in the second part, where the presentation is such that the section may be read independently of the theoretical analysis in part one. Through several approximations, the third part of the article treats with the effects of transit time upon tube noise in the planar diode.

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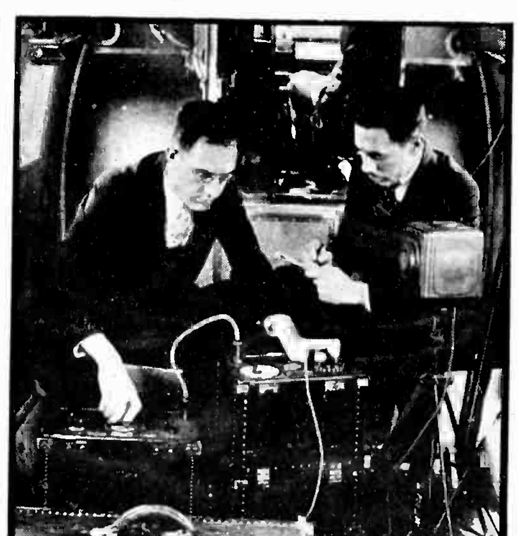
Measuring Airplane Noise



Measurements of noise inside a transport plane are being made by W. O. Osborn, research engineer, using a noise meter of his own design, in an effort to determine causes for noise. Reduction of noise is one of the most persistent problems of commercial aviation

THE INDUSTRY IN REVIEW

"Movie Dial" in Ward Radio . . . . . *by* HERBERT CHASE

A NOVEL arrangement for tuning termed the "Movie Dial" is being used in certain of the new Montgomery-Ward "Airline" radio receivers (produced by Wells Gardner & Company). Instead of using the conventional flat dial, the dial itself is printed photographically on a strip of film which is then curled into a cylinder. This cylinder is hidden to the user and is used much as a slide would be in a projection machine, except that it is not flat but remains in the form of a cylinder which is arranged for rotation about an inclined axis. What the user sees is an image of that part of the film which is brought, in tuning, into the projection aperture of the projecting device, the image being thrown on a ground glass which takes the place of the usual dial.

An accompanying illustration shows an assembly of the dial in the projector, the ground glass and several supplementary parts and, in the foreground seven zinc-alloy die castings which enter into the assembly. As will be seen, several of the die castings are of rather complex shape and would be difficult to produce economically except by die casting.

The "Movie Dial" is the dark colored cylinder of film in left background, an image of portions of which is projected on ground glass in top center panel. Die castings used in the assembly of the unit are shown separately in the foreground

On the film are three bands: shortwave, amateur and broadcast, arranged one above the other. These are brought into position by manual tuning buttons which raise and lower the film with its mounting drum through a pivoted lever in contact with the shaft on which the drum is mounted. There are also means for rotating the drum about its axis in synchronism with angular motion of the variable condenser, this being effected by a cord passing around the manual tuning knob shaft and the condenser pulley.

The shaft for the film drum is supported in a die-cast bracket which also carries the pivot for the elevating lever, and is attached to a sheet steel support which carries, in turn, the die-cast housing for the projector lenses. These lenses are mounted in a tube arranged to slide in a cored opening in the housing and are focused by moving a pin passing through an inclined slot in the housing. Another die casting, attached to the lens housing, incloses and supports a lamp which is the light source of the projector.

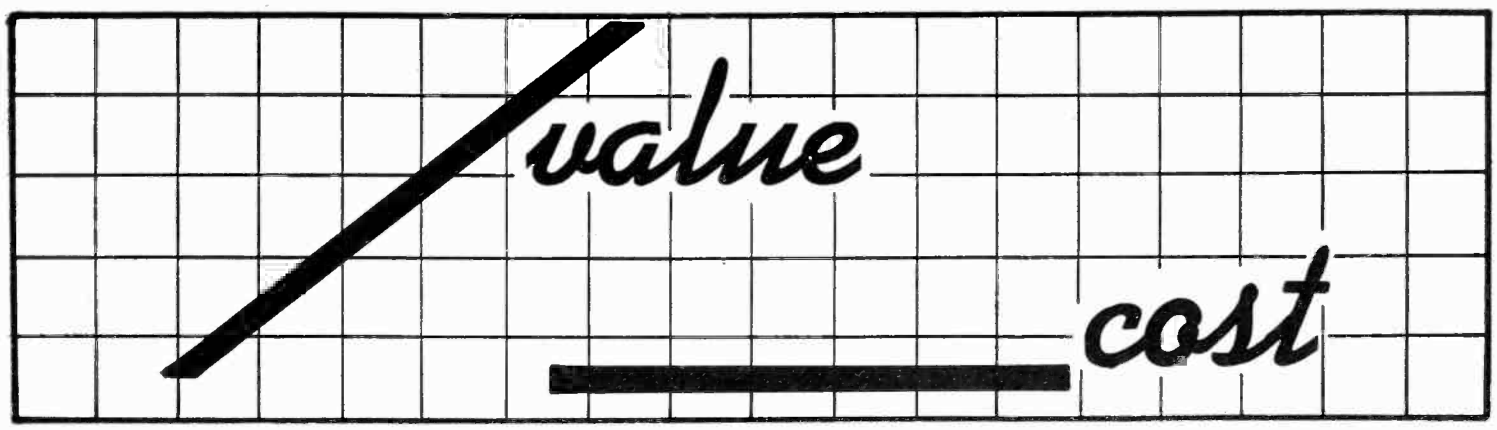
Stamped parts join the lens housing to a one-piece die-cast frame having three channels for glasses, the center one being the ground glass on which the image is projected. At each side of this is another glass, one marked Tone and the other Volume. These narrow glasses are below triangular recesses into which light bulbs are inserted, the sockets being supported by spring clips applied over rearward projections of the die casting. Of course these lamps are hidden from view, but they provide edge lighting of the glass slides below them. Back of these glasses are cards with openings through which one may see strips of metal painted red, the strips having lugs projecting rearward through slots in the die castings. Attached to the lugs are cords and return springs, the cords being carried around pullies which are attached to the tone and volume control knobs. The red strips slide up or down in tracks provided for them back of the cards when the tone and volume are varied and give a visual means for indicating the amount of change effected when the knobs are turned.

Thin fiber board completes the inclosure around the rear of the ground glass and prevents light other than that from the projector from being thrown on the ground glass. Attached to the frame for the glasses is a sheet metal part which carries the variable condenser and the shaft for the tuning knob. The image thrown on the ground glass includes letters designating the station and a scale of frequency range. There are also, separating the call letters, thin horizontal lines representing respectively Eastern, Central and Western stations. On the glass is a vertical red line, and when the call letters of more than one station are intersected by this line, the station tuned in is usually the one in the section of the country in which the listener is located. Only the more powerful stations are listed by call letters, however, and local stations are located by the frequency scale. When the set is tuned by push buttons, the movie-dial lamp is cut off and no image appears on the ground glass.

News

✦ Frederick R. Lack, formerly director of vacuum tube development at Bell Telephone Laboratories, was appointed General Commercial Engineer of the Western Electric Company. He will have charge of the sale of broadcasting equipment; aviation, police and marine radio, etc. Mr. Lack directed the installation of a radio link between Peking and Tientsin and installed the first multiplex teletypewriters for the Japanese Government, receiving in recognition the Order of the Rising Sun . . . Preliminary installation work has been started at Station WHO, Des Moines, in connection with an experimental investigation of a new system of transmission which will employ polyphase radiation to accomplish amplitude modulation and normal reception with conventional broadcast receivers. The research program is being conducted by Paul Loyet, Technical Director of the Central Broadcasting Company, and by the engineering staff of Collins Radio Company . . . Cornell-Dubilier Electric Corp. and International Standard Electric Corp. entered into a contract whereby the assistance of the engineering, manufacturing and commercial divisions of Cornell-Dubilier becomes available to International Standard for the production and sale of electric capacitors through its affiliated manufacturing companies abroad . . . C. P. Clare & Company, manufacturers of relays and electro mechanical specialties and their associate company the Logan Engineering Company, are now located in their new daylight plant at Lawrence and Lamon Avenues, Chicago. The move was necessitated by a decided and constant growth of both companies . . . Solar Mfg. Corp., New York City and Bayonne, N. J., announces the advancement of J. I. Cornell to the position of Chief Engineer. Mr. Cornell came to Solar as consulting and field engineer, having previously been Chief Engineer and Director of the Magnavox Company, section engineer on components with RCA, and with General Electric Company. He is a member of the IRE, Chairman of the RMA Committee on Electrolytic Capacitors, and a frequent contributor to engineering magazines and handbooks. . . . Hazeltine Service Corporation announces the following rearrangement of executive personnel: William A. McDonald, Vice President in Charge of Engineering; Harold A. Wheeler, Vice President and Chief Consulting Engineer; and Daniel E. Harnett, Chief Engineer . . . Supreme Instruments Corp. announces E. G. Perkins as its new Chief Engineer . . . Aerovox Corp. announces the moving of its plant and general offices from Brooklyn, N. Y. to larger quarters at New Bedford, Mass. The new plant will be in full operation by the first of February.

AN electronics PHENOMENON



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Literature

Single-ended Pentagrid Converter. The 6SA7 is described in Application Note No. 100. RCA Mfg. Co., Harrison, N. J.

Capacitor Catalog. Contains information for servicemen and dealers. Includes description of Model 73 Laboratory Type Condenser Bridge and Analyzer. Tobe Deutschmann Corp., Canton, Mass.

Capacitors. Described and illustrated in 40 page 1938-1939 Catalog No. 161, and also 12 page No. 165-A. Cornell-Dubilier Electric Corp., 1000 Hamilton Blvd., S. Plainfield, N. J.

Hand Tachometers. Bulletin 1585 describes Frahm Vibrating-Reed Hand Tachometers. Jas. G. Biddle Co., 1211 Arch St., Philadelphia, Pa.

Chime Music. "The Tower Tone" is described in leaflet. Rangertone, Inc., 201 Verona Ave., Newark, N. J.

Carbide Tool Tips. Bulletin No. 11. Gives detailed procedure to follow in brazing cemented carbide tool tips to tool holders with Easy-Flo No. 3 Brazing Alloy. Handy & Harman, 82 Fulton St., New York City.

Transmitters. 16-page bulletin "Temco Transmitters" describes and illustrates products of Transmitter Equipment Mfg. Co., Inc., 130 Cedar St., New York City.

Mercury Arc Rectifier. Allis-Chalmers *Electric Review* December, 1938 issue contains a well-illustrated story on "What goes on in the Mercury Arc Rectifier". Allis-Chalmers, Milwaukee, Wis.

Metallizing Gun. Bulletin 37. For use in spraying of copper on carbon and graphite resistors and brushes for electrical connections and in the manufacture of condensers. Bulletin P 10 describes metallizing process. Metallizing Engineering Co., Inc., 44 Whitehall St., New York City.

Rack and Panel Equipment. Catalog emphasizes streamlining and color harmony. Department EM-98, Par-metal Products Corp., 3529 41st Ave., Long Island City, N. Y.

Antenna Coupling Units. Thoroughly described in Bulletin 87. Victor J. Andrew, 6429 S. Lavergne Ave., Chicago, Ill.

Vacuum Tubes. Bulletins available on 100TH, 250TH, 35T, KY21, and RX21. Eitel-McCullough, Inc., San Bruno, Cal.

Radio World-Time Indicator. A chart to determine the time prevailing at any locality in the world. Price 50c. A. F. Ghirardi, Radio & Technical Publishing Co., 45 Astor Place, New York City.

Modern Fastening Devices. A new catalog-data book is available to engineers, production officials, and purchasing agents. A great deal of time, thought and money was expended in the preparation of this book. It is well edited; neatly indexed; illustrated, containing color pages; beautifully bound; and besides being generally useful is a beautiful example of catalog makers' art. Parker-Kalon Corp., 200 Varick St., New York City.

New Products

New Tubes

RCA MFG. CO. announces two new "single-ended" metal receiving tubes: The 6SA7, pentragrid converter, a mixer-oscillator especially for all-wave sets; and the 6SC7, twin triode amplifier intended primarily for phase-inverter service.

MICAMOLD RADIO CORP., 1087-1095 Flushing Ave., Brooklyn, N. Y., announces a new series of Ballastrons, types X, Y, and Z, intended to solve the replacement problem by an adjustment on the base. The X and Y Ballastrons replace both standard and special octal base types, while the Z Ballastron replaces the types having the four-prong or UX base.

Clamp-Ammeter

A BAKELITE ENCASED a-c clamp-ammeter, announced by Weston Electrical Instrument Corp., Newark, N. J., combines scale ranges, 10, 25, 50, 100 and 500 amps, and will measure current flow through conductors (insulated or non-insulated) up to 2¼ in. in diameter. The instrument is equipped to measure low as well as high values and any one of the 6 ranges may be selected by means of a magnetic circuit which permits only the conductor within the clamping jaw to influence the indication of the instrument. With a single conductor through the clamping jaws, current values from 1 to 500 amps can be conveniently read. It may be safely used on 660 volts a-c.

Portable Recorder

RADIOTONE, INC., 7356 Melrose Ave., Hollywood, Cal. announce a new portable recorder the HR-16 which will make up to the 16 in. size record. Other features of the unit are: Dual speed, 33⅓ or 78 rpm, changeable instantaneously, outside or inside recording, built-in radio tuner covering the broadcast band 550 to 1600 kc. It may also be used as a PA system. Literature is available.

Portable D-C Instrument

Type DP-9 "Concentric-Magnet" instrument announced by General Electric Co., Schenectady, N. Y. provides a d-c companion for the Type AP-9 a-c line. The new d-c unit combines the advantages of small case size, case styling, and general convenience with added features of mechanical simplicity, high sensitivity, and magnetic shielding. The instrument is equipped with a knife-edge pointer and mirror scale 4.1 in. long. Standard accuracy is ½ of 1 per cent of full scale value. It is available as a voltmeter, ammeter, milli-voltmeter, milliammeter, microammeter, and thermocouple voltmeter.

Audio Sound Reproducer

Because of the new design of the Vibraloc Reproducer, freedom from reflection distortion is provided and other acoustical troubles are eliminated. Added features of Model 5 are: Driver; PM dynamic heavy magnetic; voice coil impedance, approximately 3 ohms; power ratings, 5 watts normal and 8 watts peak; frequency, approximately 90 to 6000 cycles; size is 8 x 8 x 4 in. with a triangular back. A leaflet on other products is available from Vibraloc Mfg. Co., 1273 Mission St., San Francisco, Cal.

Pick-Up

MODEL AT-12 is a low priced pickup introduced by Audak Co., 500 5th Ave., New York City, for records up to 12 in. Streamlined offset head, response

to over 6000 cycles, new needle guide, new non-resonant arm, precision ball-bearings, 200-500 ohms or high impedance, describes this model.

Panel

ADDED TO PROFESSIONAL amplifiers of Universal Microphone Co., Inglewood, Cal., this new panel (containing a pre-amplifier and two-channel mixer) permits improvement in recording over the original sound source or incoming program. One input of 130 db gain provides for all low level high impedance microphones, and one input of 90 db gain provides for phonograph pickup. The equalizing gain circuit (added a few months ago) permits an 18 db increase in either the bass or the hf end of the range, or both at the same time.

Robot Motor

A MULTI-SHAFTED MOTOR having the characteristics of variable speed providing cyclic starting and stopping at 12 or less positions in 360° of rotation. The machine can be arranged to stop at each point for a period of from 5 to 60 seconds. This unit consists of a small 1 rpm motor and contact disc with rotor which starts rotating as soon as the main motor stops. This device developed by Rowe Radio Research Laboratory Co., 1103 Bryn Mawr Ave., Chicago, is useful in all cyclic operations such as testing tone and volume controls, dial drives, etc.

Crystal Holder

CRYSTALS WITH V-CUTS and holders for frequencies between 1715 and 10,000, 250 kc are available from Aviation Radio Section, RCA Mfg. Co., Camden, N. J. Between —40° C and +55° C the frequency will not depart from the specified frequency by more than ±0.015 per cent.

Humbucking Transformers

TWO SHIELDED TRANSFORMERS for use in low level input circuits where hum pickup must be kept to a minimum has been introduced by Kenyon Transformer Co., Inc., 840 Barry St., New York City.

Oscillator, Amplifier, Analysers

General Radio Co., Cambridge, Mass., announces several new instruments:

TYPE 760-A SOUND ANALYZER is for analyzing the noise and vibration generated by mechanical and electrical equipment. It consists of a degenerative, selective amplifier and a logarithmic vacuum-tube voltmeter. Response frequency can be varied between 25 and 7500 cycles by means of a rotary dial and a set of push-button switches. Usable output indications can be obtained with inputs ranging from 1 millivolt to 10 volts.

TYPE 736-A WAVE ANALYZER features a broadband flat-top filter which uses 3 quartz bars operated at 50 kc. The pass band is 4 cycles wide at the top, and the response is down 15 db at 5 cycles. Normal input impedance is 1 megohm. A 100,000 ohm potentiometer is provided as an alternate input system.

TYPE 715-A, D-C AMPLIFIER, is designed mainly for use with graphic recorders in industrial applications for amplifying to usable levels small d-c voltages from phototubes, thermometers, etc. Four ranges are provided, giving an output of 5 ma into a 5000 ohm load for input voltages of 0.1, 0.2, 0.5 and 1.0 volt, respectively. The maximum gain is 50,000 micromhos, expressed as a transconductance. It is a-c operated.

TYPE 700-A WIDE-RANGE beat-frequency oscillator delivers a substantially constant output at frequencies between 50 cycles and 5 Mc and can be used to supply a test voltage for measuring the transmission characteristics of wide-band system such as television amplifiers and coaxial cables; or a power source for general laboratory measurements; and for modulating signal generators. The frequency range is 50 cycles to 40 kc, and 10 kc, to 5 Mc. Both scales are direct-reading.

Recording Head

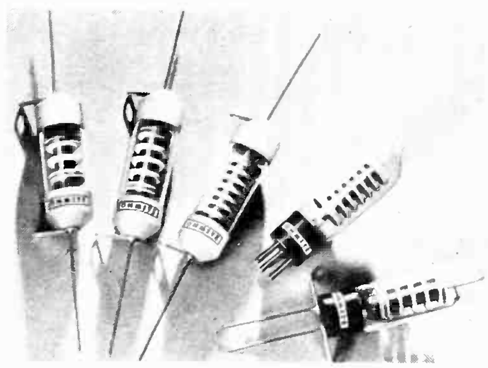
SOME OF THE features of Model RC-1 cutting head of The Brush Development Co., 3322 Perkins Ave., Cleveland, O. are: High fidelity ± 3 db. 30-10,000 cps; no change in quality with depth of cut; easily adaptable to any carriage; and crystal element waterproofed, hermetically sealed case. Booklet describes this item in detail.

Bakelite Relay Covers

A NEW COVER FOR Ward Leonard, Mount Vernon, N. Y., midget type relay is available for use where these relays with molded base are mounted on a panel. The covers are of modern design in molded bakelite and are held in place by a "snap on" fit to the base, sufficiently tight to resist accidental loosing.

Precision Resistors

To provide full protection against severe atmospheric conditions in industrial, coastal, marine and tropical locations, and to insure sustained accuracy and noise-free performance in exacting applications, Ohmite Mfg. Co., 4835 Flournoy St., Chicago, Ill., makes available a commercial series of hermetically glass-sealed precision resistors. These units are non-inductively pie-wound on porcelain in 2, 4, 6 and 8



sections with the terminals emerging through vacuum-type glass seals. One watt rating is 1% accurate (or closer tolerance when required). Resistances range from 0.1 ohm to 2 megohms.

Ohmite also announces a complete line of hermetically-sealed and standard type precision resistors for voltmeter multipliers, etc.

Unidirectional Microphone

An instrument combining the output of non-directional pressure unit with a by-directional ribbon unit with a cardioid response has been developed by Western Electric Co., New York City. Complete technical data with response characteristics are given in bulletin 639-A.

Kontak Unit

String instruments can now be played through home radio sets with the new Amperite Co., (561 Broadway, New York City), high output Kontak microphone, which is connected to the phono input or directly across the volume control. Its output level is —30 db. The response is flat over the range of 60 to 8000 cps ± 1 db.

With an adjustable clamp, the Kontak unit can be attached to any instrument in any way. It is adjustable from 1/16 to 1¼ in. and will therefore take any bridge from a small mandolin to that of a double bass.

Resistors

Developed for high voltage protective and measuring devices, these new resistors, employ the metallized type element in a spiral formation on a ceramic base. International Resistance Co., Philadelphia, Pa., announce that they are available in five standard sizes, ranging from the Type MVG, 4 watts, 5,000 volts d-c, 6,000 ohms minimum, 150 megohms maximum on a tube 2 x 7/16 in., to the Type MVR resistor which has a power rating of 150 watts; a d-c voltage rating of 100,000 and a minimum ohms rating of 0.35 megohms with a maximum of 10,000 megohms.

IRC precision wire wound resistors in accuracies up to 1/10 of 1%, employ an ingenious method for bringing both terminals out at one end. This method eliminates the problems of shorting and breakage. The base wherein the resistance wire is returned internally through the ceramic is completely insulated and protected from windings or mounting bolts and end leads of the resistance wire are not exposed.

PROFESSIONAL SERVICES

(Rates on Application)

British Patents

Electron Tubes

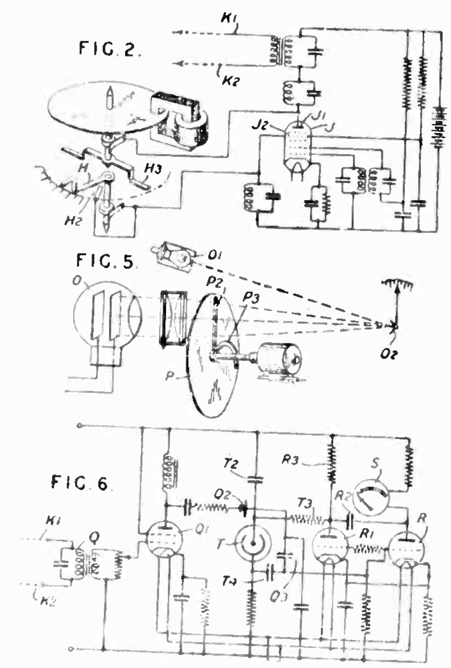
Multiplier Tubes. No. 477,916, D. S. Loewe; No. 477,347, Marconi. No. 477,345, Marconi. No. 478,001, Marconi. No. 478,153, No. 478,262, G. E. No. 478,413, Philips. No. 478,426, Zeitline. No. 478,613, G. E. Co. No. 478,641, Zeitline. No. 478,813, Marconi. No. 478,967, Marconi. No. 478,970, Marconi. No. 479,978, M-O Valve Co. No. 480,263, Baird. No. 480-786, Thomson-Houston. No. 481,020, Thomson-Houston. No. 481,750, G. E. Co. No. 481,996, G. E. Co. No. 482,026, Farnsworth. No. 482,454, Ferranti. No. 483,575, Marconi. No. 483,586, Marconi. No. 484,078, Marconi. No. 484,099, Marconi. No. 484,160, Marconi Co.

Cathode Ray Tubes. No. 477,874, Farnsworth. No. 477,406, Baird. No. 477,539, Baird. No. 477,668, Telefunken. No. 478,083 and 478,095, Ferranti. No. 478,121, Zeitline. No. 478,200, Westinghouse. No. 478,260, Fernseh. No. 478,410, Zeiss Ikon. No. 478,475, Marconi. No. 478,499, Zeitline. No. 478,666, Fernseg. No. 478,852, Philips. No. 478,971, Marconi. No. 479,024, Holman. No. 479,064, Thomson-Houston. Nos. 479,226 and 479,270, cold cathode tubes, Compagnie Fabrication des Compteurs. No. 479,318, Farnsworth. No. 479,356, J. W. Strange. No. 479,420, Thomson-Houston. No. 479,471, Fernseh. No. 479,750 and 479,761, Baird. No. 479,961, Gluhlampen. No. 480,073, Farnsworth. No. 480,275, Baird. No. 480,672, Loewe. No. 480,691, Baird. No. 480,711, Marconi. No. 480,779, Loewe. No. 480,859, J. Loeb. No. 480,946, L. Klatzow. No. 480,948, F. H. Nicoll. No. 480,996, ERPI. No. 481,094, Thomson-Houston. No. 481,430, Loewe. No. 481,434, Marconi. No. 481,445, Loewe. No. 481,516, Baird. No. 481,549, Standard Telephones. No. 481,556, Philips, No. 481,563, H. G. Lubszynski.

Heat Treatment. Temperature of surface controls shut-off valve via phototube. F. S. Deneen. No. 470,003.

Sorting. Phototube apparatus for sorting or measuring objects as to dimensions. J. R. Desch. No. 480,042.

Remote Metering. Meter readings transmitted as pairs of impulses so that the ratio of the intervals between two



impulses or a pair and two successive pairs is a measure of the reading. Reyrolle & Co. No. 480,708.

Fuel Supply Control. Photoelectric means of controlling fuel to oil burner. Bailey Meter Co. No. 480,730.

Spray Control. Dusting or spraying bricks interrupt light beam. Marston Valley Brick Co. No. 480,922.

Weighing Control. In a calculating device combined with a weighing machine the weight, price per unit weight, and cost are automatically printed or registered by phototube. D. Broido. No. 481,798.

Copying System. Production of engravings by scanning by phototube. J. W. Dalton. No. 481,985.

Burglar Alarm. Two beams of light close beside each other, each beam falling on a sensitive surface, etc. L. M. Ericsson. No. 482,322.

Delivery Apparatus. Metal sheets leaving a conveyor are formed into successive groups of predetermined number by apparatus responsive to the passage of the separate sheets. Jones & Laughlin Steel Co. No. 482,498.

Folding Machine. Phototube control of paper folding machine. Hoe & Co. No. 482,578.

Grinding Machine Control. Lund. Ltd. No. 482,741.

Colorimeter. Non-visual trichromatic colorimeter. G. E. Co. No. 483,-505.

SEARCHLIGHT SECTION

(Classified Advertising)

EMPLOYMENT : **"OPPORTUNITIES"** : EQUIPMENT
BUSINESS : : USED OR RESALE

UNDISPLAYED —RATES— **DISPLAYED**

10 CENTS A WORD. MINIMUM CHARGE $2.00
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New advertisements must be received not later than January 30th for the February issue

WANTED

Experienced **auto** and **household radio engineers** and **mechanical designers.** Technical training and actual design experience required.

COLONIAL RADIO CORPORATION
254 Rano Street Buffalo, New York

POSITION VACANT

TECHNICAL CORRESPONDENT; young graduate Engineer with at least two years actual set design experience. Active licensed amateur preferred. Give full details of experience, salary desired, etc., first letter. P 181, Electronics, 520 N. Michigan Ave., Chicago, Ill.

POSITIONS WANTED

ELECTRONIC ENGINEER, college graduate, age 32, twelve years extensive experience in design, development and production of industrial and electron tubes. PW-168, Electronics, 330 W. 42nd St., New York, N. Y.

BROADCAST ENGINEER, now employed by large air transport company as airport service and installation technician, desires position in broadcast field. Experienced extensively in all phases including transmitter and control operator, studio and commercial announcer. In present position for three years. Excellent references. PW 182, Electronics, 330 W. 42nd St., New York, N. Y.

BUSINESS OPPORTUNITY

Inventor Wishes to Organize Company

To promote a narrow band width system of television. Demonstration to interested parties. Henry J. Walczak, 49 Osgood St., Springfield, Mass.

REPRESENTATIVES WANTED

With following of jobbers, factories, etc., to handle line of precision built test equipment at attractive prices. Features GR, National, Hammarlund, controls and components. Excellent commission and bonus set-up. Opportunity to get in on the ground floor of a company that has advanced on the merit of its fair price plus quality policy.

RW-180, Electronics,
520 N. Michigan Ave., Chicago, Ill.

SALESMEN WANTED

RADIO HAMS to represent us in the sale of short-wave diathermy units to physicians. Good territories open in N. C., Ga., Fla., Ky., W. Va., Minn., N. J., Texas and the Southwest. Liberal commission. Estab. 60 yrs.

McIntosh Elec. Corp., 223 N. California Ave., Chicago

MICROPHONE REPAIRS

CARBON—VELOCITY—DYNAMIC
ALL MAKES—ANY CONDITION
Write for Quotations

ELECTRO-VOICE MFG. CO., INC.
334 E. COLFAX AVE.
SOUTH BEND, INDIANA

New "SEARCHLIGHT" Advertisements

must be received by January 30th to appear in the February issue.

Address copy to the Departmental Advertising Staff

Electronics
330 West 42d St., New York City

If it's radio, we have it!

AUTHORIZED DISTRIBUTORS

2 completely stocked Terminal radio supply houses now serve broadcast stations, engineers and laboratories. Free delivery service. Both stores open evenings till 8:00 P.M.

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ELECTRON TUBE EQUIPMENT

Huge Stock of Equipment of Every Type and Variety

KAHLE ENGINEERING CORPORATION

Specialists in Equipment and Methods for the Manufacture of Neon Tubes, Radio Tubes, Incandescent Lamps, Photo Cells, X-ray Tubes, etc.

941 DeMott St., North Bergen, N. J.

DEPENDABLE

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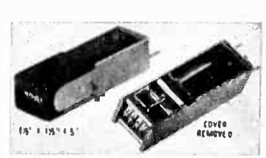
ELECTRONIC TUBE EQUIPMENT

A complete line of used equipment for the manufacture of Radio Tubes, Neon Tubes, Incandescent Lamps, etc.

Write for Bulletin showing savings from 25 to 75%

EISLER ELECTRIC CORP.
534 39th Street, Union City, N. J.

SOLENOID COUNTERS



New four-wheel counters—1300 ohm 24-48 v. d.c.

These counters have many applications in photoelectric cell work, broadcasting stations, and industrial uses. Original cost $6.50; while limited stock lasts, $2.00 each; 3 for $5.00. C.O.D. only. Perfect cond. guaranteed or money refunded.

FEDERAL SALES COMPANY
26 S. Jefferson St. CHICAGO, ILL.

CALLING ALL ENGINEERS

Everything in radio for laboratories, broadcast stations, and industrials.

We carry a tremendous stock of radio equipment.

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Write for FREE
New illustrated booklet

"A Tested Plan for A Future in Radio"

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GRADUATE COURSE IN

TELEVISION ENGINEERING

The ***Graduate Division of Newton Institute*** announces a home study course in Television Engineering designed to meet the specific needs of Radio Engineers.

Formal study of basic principles and current practice prepares for television development and design. Extensive treatment embraces latest experiments and achievements both here and abroad. B.S. in E.E. (or its equivalent) prerequisite to admission. For full details address:

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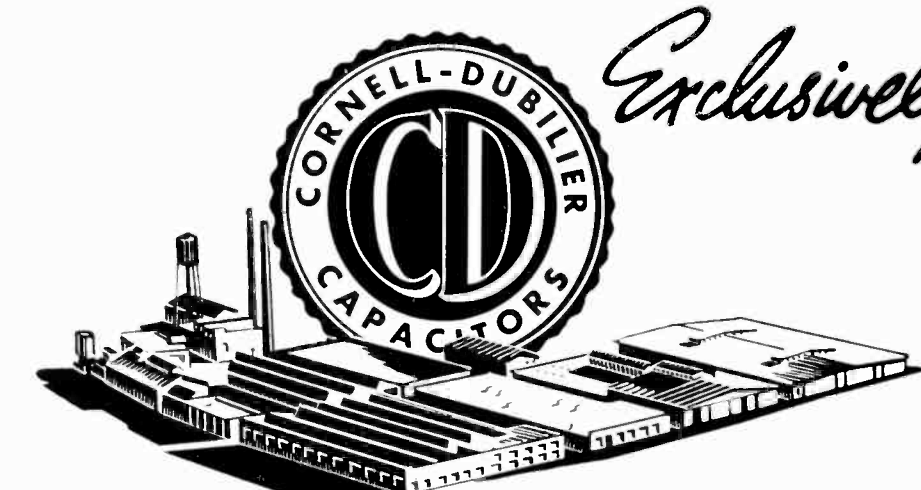
RADIO TUBE MAKING MACHINERY

14—No. 3 Trimount Rotary Vacuum Pump.
4—No. 66-M Eisler Triple Vacuum Pump.
3—No. 100 Eisler Gas Heated Soldering Irons.
4—No. 61 Power Driven Preheaters.
4—No. 63 Hand Operated Preheaters.
6—No. 57BT—6 head Sealing Machines.
5—No. 23-7T—7 Head Stem Machines.
2—6 Head Stem Machines.
2—No. 50 Tabulating Machines with Hopper feed attachment.
2—No. 89-M—40 Head Basing Machines.
2—No. 18 Automatic Flare Machines.
1—No. 102F Flare Punching Machine for punching flares in one side.
1—No. 13R Tipless exhaust tube Bending Machine.
1—No. 105—6 Head cane glass automatic indexing & bead making machine.
1—No. 5 Beach-Russ Backing-up Vacuum Pump.
14—Type CD 2 HP Westinghouse shunt wound DC motor, 230 Volt, 1725 RPM.

KELLOGG SWITCHBOARD & SUPPLY CO.
6650 S. Cicero Avenue, Chicago, Ill.



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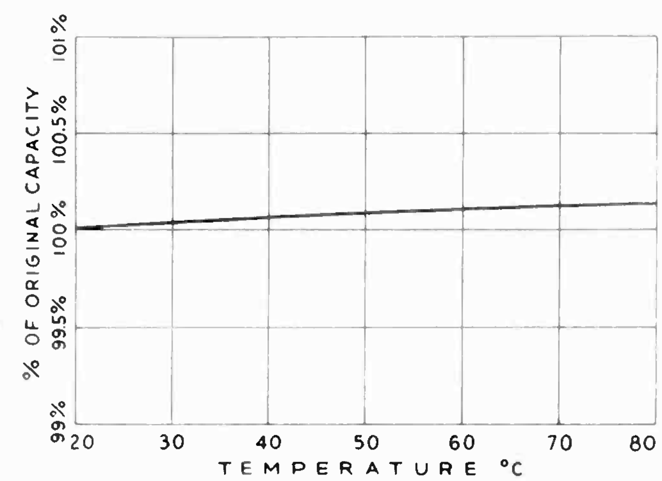
THEY SPEAK FOR THEMSELVES

Erie SILVER-MICAS

FOR ELIMINATING CONDENSER DRIFT

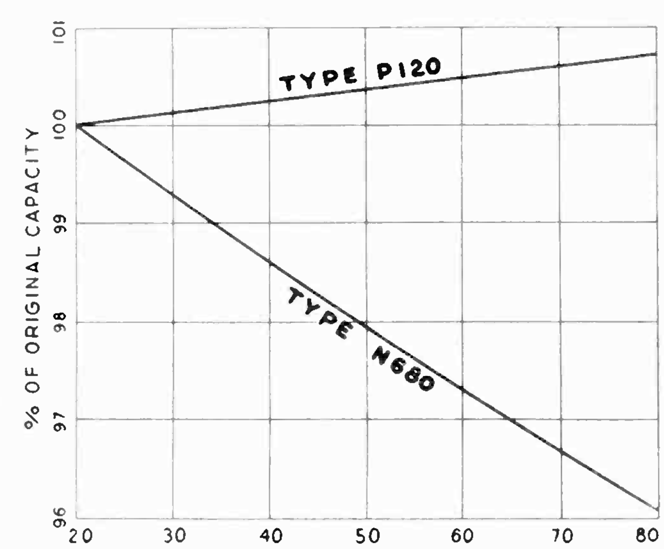


TYPE F ERIE SILVER MICA CONDENSER

Erie CERAMICONS

REG. U.S. PAT. OFF.

FOR COMPENSATING FOR FREQUENCY DRIFT



ERIE CERAMICONS

One look at these two charts tells why Erie Silver Mica Condensers and Erie Ceramicons are indispensible for keeping push button tuned receivers "tuned on the nose."

Erie Silver Micas eliminate condenser frequency drift because their temperature coefficient is only +.000025/°C—negligible for all practical purposes. And when frequency drift is present in other circuit elements, the use of a proper value Erie Ceramicon can compensate for that change. These silver-ceramic condensers have a definite, linear and reproducable temperature coefficient.

Both of these units have been thoroughly tried and proven in the laboratory and in actual service. Their characteristics are unusually good, and their operation is unbelievably dependable.

We will be glad to send you samples and complete engineering data on these condensers.

ERIE RESISTOR CORPORATION, *Erie, Pa.*

TORONTO, CANADA • LONDON, ENGLAND • PARIS, FRANCE-J.E.CANETTI CO.

MANUFACTURERS OF RESISTORS • CONDENSERS • MOLDED PLASTICS

RCA Introduces

New WHITE SCREEN TELEVISION TUBES

906-P4—WHITE SCREEN...$15.00

Introducing the new RCA-906-P4, a 3-inch television Kinescope. Similar to the present RCA-906 Cathode-Ray Tube, this new tube features a white fluorescent screen—*and* an unusually low cost! In addition to its low inital cost, this new tube provides low circuit cost because of its low voltage operation. Has conductive coating which minimizes deflecting-plate loading and prevents drifting of the pattern with changes in bias.

1802-P4—WHITE SCREEN...$27.50

Introducing the 1802-P4, a 5-inch television Kinescope having electrostatic deflection and white screen. This tube provides excellent quality television pictures. *The deflection sensitivity is such that the beam may be deflected across the entire screen with no more voltage than is required for full deflection on 3-inch tube.* Separate terminals are provided in the new Magnal 11-pin base for each deflecting plate.

1802-P1—GREEN SCREEN...$24.75

Introducing the 1802-P1, a new 5-inch oscillograph tube which is similar to the 1802-P4 except for its green screen. In oscillographic application the 1802-P1 represents extremely high quality because it is capable of providing excellent television pictures. For television purposes this tube operates well with an anode potential of 1200 volts.

NEW RCA MONOSCOPE

The new RCA-1899 Monoscope provides a convenient source of video signal for testing television equipment and for demonstrating television principles. The pattern contains calibrated resolution wedges to indicate the amount of detail the associated equipment can resolve. Other features of the pattern provide tests for linearity of scanning, spot defocusing, amplitude response, frequency response, phase response, and general quality of picture reproduction. Price $95.00.

RCA presents the Magic Key every Sunday, 2 to 3 P.M., E.S.T., on the NBC Blue Network

RCA Radio Tubes—first in metal, foremost in glass, finest in performance

RCA *for* TELEVISION

RCA Manufacturing Company, Inc., Camden, N. J. A Service of the Radio Corporation of America